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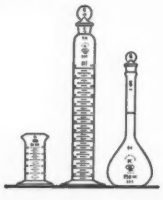

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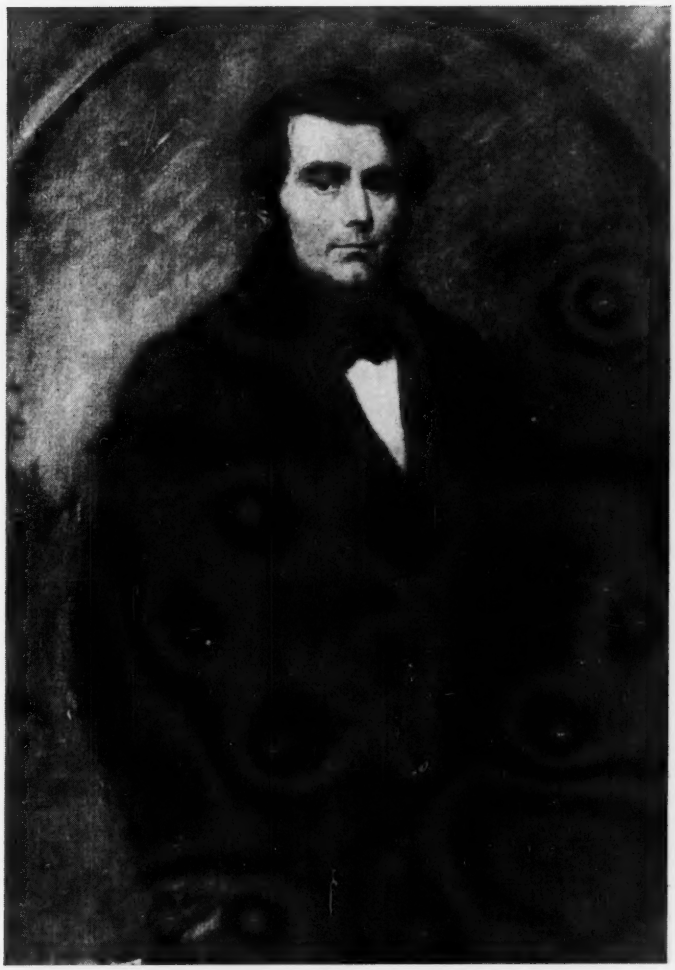

*Portrait in Heilbronn City Hall*

## (Julius) Robert Mayer (1814–78)

*Contributed by Ralph E. Oesper, University of Cincinnati*

(For further information about (Julius) Robert Mayer, see page 134).

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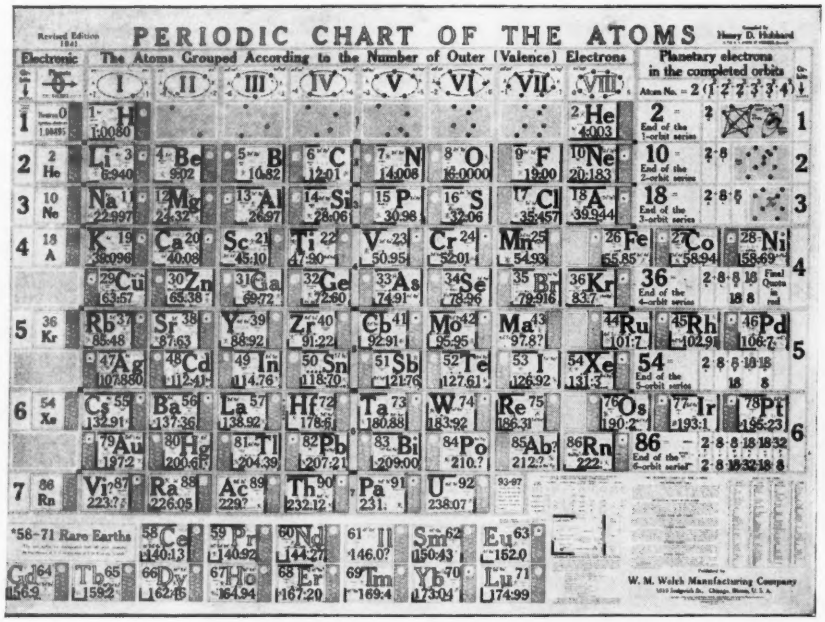


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# Editor's Outlook

MUCH of what we wanted to say this month has already been said in an editorial in the February number of *Industrial and Engineering Chemistry*. Its main import can be summed up in one paragraph:

"When it is explained that chemists, physicists, mathematicians, and their like must perform their war work in their professional capacities, some fail to realize that this is the best strategy for the country and not an effort to obtain deferment by professional classes. The soundness of this procedure is recognized generally and especially in places of authority. And yet the recognition has not spread sufficiently in some quarters to prevent disastrous waste."

It is pointed out, however, that "places of authority" evidently do not include the military, or if so, military authorities are so preoccupied with other matters that they do not appreciate the seriousness of the situation. A large number of trained chemists have knowingly been enrolled in the army and assigned to work which allows their technical training to go wasted. And this in face of the fact that other governmental authorities are crying for more chemists to speed up production.

The Army and Naval R.O.T.C. units have no small part in this matter. At some of our colleges *100 per cent* of the senior chemists and chemical engineers are enrolled in these units, and, glancing down the list, from 20 to 30 per cent seems a fair average. Few, if any, of these will reach the chemical industry; they are headed straight for the combat forces. Not that we object to more and better fighters; and not that we want to interfere with the training of reserve officers. But we do not think that it would impose any hardship on the R.O.T.C. units if they would keep their hands off our promising chemists, physicists, and engineers. What are we training them for, anyway?

It now seems possible—perhaps probable—that the government will furnish some sort of student aid for those in training for the technical professions. We venture to prophesy that only those students who are eventually likely to be *available* for industrial technical service will be eligible for aid.

As to the urgent need and limited supply of chemists, the results of the recent questionnaire from the Office of the Secretary of the A. C. S. are worth noting. The departments of chemistry of 450 of our colleges and universities, all together, could find only a mere handful of their graduates who are unemployed. And it seems that even these are "unemployable." Without exception, the institutions report a greatly increased demand for chemists this year over that of last.

Twenty-eight of the leading chemical manufacturing concerns, including many actively engaged in war industries, similarly reported that the shortage of chemists had greatly increased in the last year, and practically without exception they expect it to increase still further during the next year. As an estimate of their needs for trained chemists during 1942 they set a total figure of 2150 men. If the same proportion holds throughout the whole chemical industry, it is certain that the 8000 chemists and chemical engineers who will be graduated this spring will not be nearly enough.

And a point specially worth noting is that an insufficient proportion of graduate students are being trained. The industries say that of the men they employ this year 30 per cent should have Doctors' and Masters' degrees; while only 20 per cent of those graduated by our institutions this year will fulfil this specification.

President Conant, of Harvard, in his recent report for the year 1940–1941, brought up several of the fundamental points involved in this matter of the supply and demand of chemists. He says:

"Even now the . . . serious contradiction existing with respect to the supply of trained manpower is not fully understood. A consideration of this vital problem is important both to the efficiency of the national effort and to an intelligent development of the part which our universities can best play in the task which lies before us. In the first place, an authoritative and comprehensive survey of the country's needs for trained men and women for the war should be made at once. Such a survey, I understand, is now planned by one branch of the federal government."

He then suggests that, following such a survey, a policy should be adopted which is essentially a very much further extension of the principle of Selective Service. A sufficient number of men with the proper training and qualifications to fulfil each of the necessary tasks revealed by the survey should be selected and assigned to that particular work. As this would affect the chemical profession it would mean, presumably, that the actual need for chemists in the production industries would be definitely ascertained. Students of predraft age, who have the promise, qualifications, and ability to make good chemists would then be picked out in sufficient number to fill the evident needs and *assigned* to their period of training. Later, they would presumably be put to work in technical positions and perhaps even *prohibited* from combat service.

While this is somewhat vague it nevertheless begins to make sense. We very much need a practical implementation of this general idea.

The plan which comes the nearest to doing this of any of which we have yet heard is one brought to our attention by Dr. Harold S. Booth, of Western Reserve University. It has been called the "U. S. Professional Training Reserve." The idea is that qualified students in training for certain designated professions, including chemistry, shall, after their first year, be enrolled in the Professional Training Reserve, which is intended to have as reputable standing as the Army and Naval Reserve Corps. Upon the certification of a student to the Reserve he would be put in a deferred classification by his Selective Service board; his continuance in the Reserve would depend upon his maintaining a proper standard; and at the end of his training, the length



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of which would be determined by his ability and record, industry would have the first call upon his services.

Administrative details would seem to offer no more difficulty than that incidental to any large-scale plan, and it would do three things which seem very necessary in view of the present situation:

1. It would assure a reservoir of trained personnel from which industry and the professions could draw.
2. It would relieve the uncertainties which surround the present operation of the Selective Service System, to which the proposed plan would virtually be an adjunct.
3. It would lessen, if not prevent, the competition between industry and the professions on the one hand and the armed services, including the R.O.T.C., on the other. The Professional Training Reserve would be a tangible and respectable way in which a student might choose to serve, without requiring any apology to his conscience or to others.

WE HAVE received a number of comments on our observations in last month's Outlook and the list of "Ten Questions" in the same number. It has been suggested that the general argument might be extended a little, here and there. We therefore take the immediate opportunity to do so, while the question is still fresh.

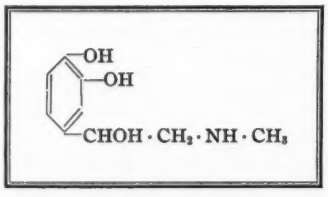
From the very start, there has been no change in the policy of the Occupational Deferment division of the Selective Service System. Colonel J. F. Battley, who is in charge of this division, as well as General Hershey himself, has repeatedly gone on record in support of the necessity of retaining technically trained men in their technical fields. Whatever doubt there may be on this score elsewhere, there is none in the inner circles and among the higher-ups.

Perhaps it would be well to emphasize further the responsibility of the individual for seeing that his case is properly appreciated by his local board, and if he is a professional chemical student or a chemist employed in necessary work and he is *nevertheless* given a I-A classification, it is not only his privilege but his *duty* to register an appeal within the ten days legally allowed. Colonel Battley, speaking at the St. Louis meeting of the A. C. S., emphasized the responsibility of each of us for seeing that the clear intention of the Selective Service Act is carried out.

The supply of graduate students is beginning to present a serious problem. This will affect the standard and efficiency of instruction, in which graduate students participate as assistants. Selective Service plays some part, at least, in this. In his recent statement to state directors (I-347, January 12, 1942), General Hershey stresses the importance of the deferment of both students and *instructors* in technical fields, such as chemistry and chemical engineering. At his request material has been collected for a statement on the urgent need for graduate-trained men in the technical fields.

We proposed the question whether chemical training now will lead into a blind alley after the war. In answering this we thought it well to put the emphasis upon the present emergency and to imply that conditions after the war must, for the moment, be left to look out for themselves. We do not think it improper, however, that students should be thinking of their own futures—as indeed they are. We find many of them even now balancing the possible consequences of choosing this or that branch of service. It should be obvious to our young chemists in training that when the time comes for them to find permanent, stable places in their profession experience in the "combat army" in World War II will have nothing but sentimental value, while service in the "production army" will be chemical experience worth having had. Those who have been out of contact with their profession for a long period may find it difficult to return to it. We do not offer this as an argument superior to the country's urgent need. We are not interested in limiting enrolment in the combat forces—far from it! But we *are* interested in putting trained technicians to work in the places where they can *best* serve.

## FORMULA OF THE MONTH




*dl*-Adrenaline

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# Samuel Johnson's "Life of Boerhaave"

EDWARD R. ATKINSON *University of New Hampshire, Durham, New Hampshire*

SHORTLY before his death in 1738, Herman Boerhaave wrote a brief sketch of his life; his student, Albert Schultens, used this as the basis for a commemorative eulogy published in Latin[1] and this latter work is considered to be one of the standard sources of biographical data on Boerhaave.[2]

In 1739 Samuel Johnson had been in London two years and was engaged in writing brief essays for the *Gentleman's Magazine* and other periodicals. As one contribution to a series later known as "Lives of Eminent Persons," Johnson wrote his sketch of Boerhaave. His technic was that of a direct translation of Schultens's eulogy, interspersed with Johnsonian reflections. Two enlarged versions of the sketch appeared at later dates. The first of these contained short criticisms of Boerhaave's "Institute," "Aphorisms," and "Chemistry"; it was printed in Robert James's famous "Medical Dictionary" and in the Davies' edition of Johnson's "Miscellaneous and Fugitive Pieces" (1773). The second contained, besides the three additions just mentioned, six paragraphs on Boerhaave's "Indexes"; it appeared in the *Universal Magazine* for 1752. Dr. Allan T. Hazen has made a complete study of these additions[3] and has concluded that they are genuinely Johnsonian.

In his "Life of Johnson," Boswell tells us that in writing the Boerhaave biography Johnson discovered "that love of chymistry which never forsook him" and that Johnson was throughout his life fond of performing chemical experiments. During the tour to the Hebrides, Johnson and Boswell spent one forenoon at the home of Boswell's uncle. The uncle was an elegant scholar and a physician bred in the school of Boerhaave and Johnson was pleased with his company.

The text which follows is the original as it appeared in the *Gentleman's Magazine* for 1739.[4]

The following account of the late Dr. Boerhaave, so loudly celebrated, and so universally lamented through the whole learned world, will, we hope, be not unacceptable to our readers: We could have made it much larger, by adopting flying reports, and inserting unattested facts; a close adherence to certainty has contracted our narrative, and hindered it from swelling to that bulk, at which modern histories generally arrive.

Dr. Herman Boerhaave was born on the last day of December, 1668, about one in the morning, at Voorhout, a village two miles distant from Leyden: his father, James Boerhaave, was minister of Voorhout, of whom his son,[5] in a small account of his own life, has given a very amiable character, for the simplicity and openness of his behaviour, for his exact frugality in the management of a narrow fortune, and the prudence, tenderness, and diligence, with which he educated a numerous family of nine children. He was eminently skilled in history and genealogy, and versed in the Latin, Greek, and Hebrew languages.

*From the John Opie portrait*
SAMUEL JOHNSON

His mother was Hagar Daelder, a tradesman's daughter of Amsterdam, from whom he might, perhaps, derive an hereditary inclination to the study of physick, in which she was very inquisitive, and had obtained a knowledge of it not common in female students.

This knowledge, however, she did not live to communicate to her son; for she died in 1673, ten years after her marriage.

His father, finding himself encumbered with the care of seven children, thought it necessary to take a second wife, and in July 1674, was married to Eve du Bois, daughter of a minister of Leyden, who, by her prudent and impartial conduct, so endeared herself to her husband's children, that they all regarded her as their own mother.

Herman Boerhaave was always designed by his father for the ministry, and with that view instructed by him in grammatical learning, and the first elements of languages; in which he made such a proficiency, that he was, at the age of eleven years, not only master of the rules of grammar, but capable of translating with tolerable accuracy, and not wholly ignorant of critical niceties.

At intervals, to recreate his mind, and strengthen his constitution, it was his father's custom to send him into the fields, and to employ him in agriculture and such kind of rural occupations, which he continued through all his life to love and practise; and by this vicissitude of study and exercise preserved himself, in a great measure, from those distempers and depressions which are frequently the consequences of indiscreet diligence, and uninterrupted application; and from which students, not well acquainted with the constitution of the human body, sometimes fly for relief to wine instead of exercise, and purchase temporary ease by the hazard of the most dreadful consequences.

The studies of young Boerhaave were, about this time, interrupted by an accident, which deserves a particular mention, as it first inclined him to that science, to which he was by nature so

[1] SCHULTENS, *"Oratio academica in memoriam Hermanni Boerhaave . . .,"* Lugd. Batav., **1738,** 4°.
[2] Max Speter in BUGGE, "Das Buch der grossen Chemiker," Verlage Chemie, Berlin, **1929,** Vol. I, p. 204.
[3] HAZEN, *Bull. Inst. History Med.*, **4,** 455 (1936).
[4] Reprinted in "The works of Samuel Johnson," London, **1796,** Vol. 12, p. 11.
[5] Latin footnote omitted.

well adapted, and which he afterwards carried to so great perfection.

In the twelfth year of his age, a stubborn, painful, and malignant ulcer, broke out upon his left thigh; which, for near five years, defeated all the art of the surgeons and physicians, and not only afflicted him with most excruciating pains, but exposed him to such sharp and tormenting applications, that the disease and remedies were equally insufferable. Then it was that his own pain taught him to compassionate others, and his experience of the inefficacy of the methods then in use incited him to attempt the discovery of others more certain.

He began to practise at least honestly, for he began upon himself; and his first essay was a prelude to his future success, for, having laid aside all the prescriptions of his physicians, and all the applications of his surgeons, he, at last, by tormenting the part with salt and urine, effected a cure.

That he might, on this occasion, obtain the assistance of surgeons with less inconvenience and expense, he was brought, by his father, at fourteen, to Leyden, and placed in the fourth class of the publick school, after being examined by the master: here his application and abilities were equally conspicuous. In six months, by gaining the first prize in the fourth class, he was raised to the fifth; and in six months more, upon the same proof of the superiority of his genius, rewarded with another prize, and translated to the sixth; from whence it is usual in six months more to be removed to the university.

Thus did our young student advance in learning and reputation, when, as he was within view of the university, a sudden and unexpected blow threatened to defeat all his expectations.

On the 12th of November, in 1682, his father died, and left behind him a very slender provision for his widow and nine children, of which the eldest was not yet seventeen years old.

This was a most afflicting loss to the young scholar, whose fortune was by no means sufficient to bear the expenses of a learned education, and who therefore seemed to be now summoned by necessity to some way of life more immediately and certainly lucrative; but, with a resolution equal to his abilities, and a spirit not so depressed and shaken, he determined to break through the obstacles of poverty, and supply, by diligence, the want of fortune.

He therefore asked and obtained the consent of his guardians to prosecute his studies as long as his patrimony would support him; and, continuing his wonted industry, gained another prize.

He was now to quit the school for the university, but, on account of the weakness yet remaining in his thigh, was at his own entreaty, continued six months longer under the care of his master, the learned Winschotan, where he once more was honoured with the prize.

At his removal to the university, the same genius and industry met with the same encouragement and applause. The learned Triglandius, one of his father's friends, made soon after professor of divinity at Leyden, distinguished him in a particular manner, and recommended him to the friendship of Mr. Van Apphen, in whom he found a generous and constant patron.

He became now a diligent hearer of the most celebrated professors, and made great advances in all the sciences; still regulating his studies with a view principally to divinity, for which he was originally intended by his father, and for that reason exerted his utmost application to attain an exact knowledge of the Hebrew tongue.

Being convinced of the necessity of mathematical learning, he began to study those sciences in 1687, but without that intense industry with which the pleasure he found in that kind of knowledge induced him afterwards to cultivate them.

In 1690, having performed the exercises of the university with uncommon reputation, he took his degree in philosophy; and on that occasion discussed the important and arduous subject of the distinct natures of the soul and body, with such accuracy, perspicuity, and subtilty, that he entirely confused all the sophistry of Epicurus, Hobbes, and Spinosa, and equally raised the characters of his piety and erudition.

Divinity was still his great employment, and the chief aim of all his studies. He read the scriptures in their original languages, and when difficulties occurred, consulted the interpretations of the most ancient fathers, whom he read in order of time, beginning with Clemens Romanus.

In the perusal of those early writers,[6] he was struck with the profoundest veneration of the simplicity and purity of their doctrine, the holiness of their lives, and the sanctity of the discipline practised by them; but, as he descended to lower ages, found the peace of Christianity broken by useless controversies, and its doctrines sophisticated by the subtilties of the schools. He found the holy writers interpreted according to the notions of philosophers, and the chimeras of metaphysicians adopted as articles of faith. He found difficulties raised by niceties, and fomented to bitterness and rancour. He saw the simplicity of the christian doctrine corrupted by the private fancies of particular parties, while each adhered to its own philosophy, and orthodoxy was confined to the sect in power.

Having now exhausted his fortune in the pursuit of his studies, he found the necessity of applying to some profession, that, without engrossing all his time, might enable him to support himself; and having obtained a very uncommon knowledge of the mathematicks, he read lectures in those sciences to a select number of young gentlemen in the university.

At length, his propension to the study of physick grew too violent to be resisted; and, though he still intended to make divinity the great employment of his life, he could not deny himself the satisfaction of spending some time upon the medical writers, for the perusal of which he was so well qualified by his acquaintance with the mathematicks and philosophy.

But this science corresponded so much with his natural genius, that he could not forbear making that his business which he intended only as his diversion; and still growing more eager, as he advanced further, he at length determined wholly to master that profession, and to take his degree in physick, before he engaged in the duties of the ministry.

It is, I believe, a very just observation, that men's ambition is generally proportioned to their capacity. Providence seldom sends any into the world with an inclination to attempt great things, who have not abilities likewise to perform them. To have formed the design of gaining a complete knowledge of medicine by way of digression from theological studies, would have been little less than madness in most men, and would have only exposed them to ridicule and contempt. But Boerhaave was one of those mighty geniuses, to whom scarce any thing appears impossible, and who think nothing worthy of their efforts but what appears insurmountable to common understandings.

He began this new course of study by a diligent perusal of Vesalius, Bartholine, and Fallopius; and, to acquaint himself more fully with the structure of bodies, was a constant attendant upon Nuck's publick dissections in the theatre, and himself very accurately inspected the bodies of different animals.

Having furnished himself with this preparatory knowledge, he began to read the ancient physicians in the order of time, pursuing his enquiries downwards from Hippocrates through all the Greek and Latin writers.

Finding, as he tells us himself, that Hippocrates was the original source of all medical knowledge, and that all the later writers were little more than transcribers from him, he returned to him with more attention, and spent much time in making extracts from him, digesting his treaties into method, and fixing them in his memory.

He then descended to the moderns, among whom none engaged him longer, or improved him more, than Sydenham, to whose merit he has left this attestation, "that he frequently perused him," and always "with greater eagerness."

His insatiable curiosity after knowledge engaged him now in the practice of chemistry, which he prosecuted with all the ardour of a philosopher, whose industry was not to be wearied, and whose love of truth was too strong to suffer him to acquiesce in the reports of others.

Yet did he not suffer one branch of science to withdraw his attention from others: anatomy did not withhold him from chemistry, nor chemistry, enchanting as it is, from the study of botany, in which he was no less skilled than in other parts of

physick. He was not only a careful examiner of all the plants in the garden of the university, but made excursions for his further improvement into the woods and fields, and left no place unvisited where any increase of botanical knowledge could be reasonably hoped for.

In conjunction with all these enquiries he still pursued his theological studies, and still, as we are informed by himself, "proposed, when he had made himself master of the whole art of physick, and obtained the honour of a degree in that science, to petition regularly for a licence to preach, and to engage in the cure of souls," and intended in his theological exercise to discuss this question, "why so many were formerly converted to Christianity by illiterate persons, and so few at present by men of learning."

In pursuance of this plan he went to Hardewich, in order to take the degree of doctor in physick, which he obtained in July 1693, having performed a publick disputation, *"de utilitate explorandorum excrementorum in aegris, ut signorum."*

Then returning to Leyden full of his pious design of undertaking the ministry, he found to his surprise unexpected obstacles thrown in his way, and an insinuation dispersed through the university that made him suspected, not of any slight deviation from received opinions, not of any pertinacious adherence to his own notions in doubtful and disputable matters, but of no less than Spinosism, or, in plainer terms, of Atheism itself.

How so injurious a report came to be raised, circulated, and credited, will be doubtless very eagerly inquired: we shall therefore give the relation, not only to satisfy the curiosity of mankind, but to shew that no merit, however exalted, is exempt from being not only attacked, but wounded, by the most contemptible whispers. Those who cannot strike with force, can however poison their weapon, and weak as they are, give mortal wounds, and bring a hero to the grave: so true is that observation, that many are able to do hurt, but few to do good.

This detestable calumny owed its rise to an incident from which no consequence of importance could be possibly apprehended. As Boerhaave was sitting in a common boat, there arose a conversation among the passengers upon the impious and pernicious doctrine of Spinosa, which, as they all agreed, tends to the utter overthrow of all religion. Boerhaave sat, and attended silently to this discourse for some time, till one of the company, willing to distinguish himself by his zeal, instead of confuting the positions of Spinosa by argument, began to give a loose to contumelious language, and virulent invectives, which Boerhaave was so little pleased with, that at last he could not forbear asking him, whether he had ever read the author he declaimed against.

The orator, not being able to make much answer, was checked in the midst of his invectives, but not without feeling a secret resentment against the person who had at once interrupted his harangue, and exposed his ignorance.

This was observed by a stranger who was in the boat with them; he enquired of his neighbour the name of the young man, whose question had put an end to the discourse, and having learned it, set it down in his pocket-book, as it appears, with a malicious design, for in a few days it was the common conversation at Leyden, that Boerhaave had revolted to Spinosa.

It was in vain that his advocates and friends pleaded his learned and unanswerable confutation of all atheistical opinions, and particularly of the system of Spinosa, in his discourse of the distinction between soul and body. Such calumnies are not easily suppressed, when they are once become general. They are kept alive and supported by the malice of bad, and sometimes by the zeal of good men, who, though they do not absolutely believe them, think it yet the securest method to keep not only guilty but suspected men out of publick employments, upon this principle, that the safety of many is to be preferred before the advantage of few.

Boerhaave, finding this formidable opposition raised against his pretensions to ecclesiastical honours or preferments, and even against his design of assuming the character of a divine, thought it neither necessary nor prudent to struggle with the torrent of popular prejudice, as he was equally qualified for a profession, not indeed of equal dignity or importance, but which must undoubtedly claim the second place among those which are of the greatest benefit to mankind.

He therefore applied himself to his medical studies with new ardour and alacrity, reviewed all his former observations and enquiries, and was continually employed in making new acquisitions.

Having now qualified himself for the practice of physick, he began to visit patients, but without that encouragement which others, not equally deserving, have sometimes met with. His business was, at first, not great, and his circumstances by no means easy; but still, superior to any discouragement, he continued his search after knowledge, and determined that prosperity, if ever he was to enjoy it, should be the consequence not of mean art, or disingenuous solicitations, but of real merit, and solid learning.

His steady adherence to his resolutions appears yet more plainly from this circumstance: he was, while he yet remained in this unpleading situation, invited by one of the first favourites of King William III to settle at the Hague, upon very advantageous conditions; but declined the offer. For having no ambition but after knowledge, he was desirous of living at liberty, without any restraint upon his looks, his thoughts, or his tongue, and at the utmost distance from all contentions, and state-parties. His time was wholly taken up in visiting the sick, studying, making chemical experiments, searching into every part of medicine with the utmost diligence, teaching the mathematicks, and reading the scriptures, and those authors who profess to teach a certain method of loving God.[5]

This was his method of living to the year 1701, when he was recommended by Van Berg to the university, as a proper person to succeed Drelincurtius in the professorship of physick, and elected without any solicitations on his part, and almost without his consent, on the 18th of May.

On this occasion, having observed, with grief, that Hippocrates, whom he regarded not only as a father but as the prince of physicians, was not sufficiently read or esteemed by young students, he pronounced an oration, *"de commendando Studio Hippocratico"*; by which he restored that great author to his just and ancient reputation.

He now began to read publick lectures with great applause, and was prevailed upon by his audience to enlarge his original design, and instruct them in chemistry.

This he undertook, not only to the great advantage of his pupils, but to the great improvement of the art itself, which had been hitherto treated only in a confused and irregular manner, and was little more than a history of particular experiments, not reduced to certain principles, nor connected one with another: this vast chaos he reduced to order, and made that clear and easy which was before to the last degree difficult and obscure.

His reputation now began to bear some proportion to his merit, and extended itself to distant universities; so that, in 1703, the professorship of physick being vacant at Groningen, he was invited thither; but he refused to leave Leyden, and chose to continue his present course of life.

This invitation and refusal being related to the governors of the university of Leyden, they had so grateful a sense of his regard for them, that they immediately voted an honorary increase of his salary, and promised him the first professorship that should be vacant.

On this occasion he pronounced an oration upon the use of mechanicks in the science of physick, in which he endeavoured to recommend a rational and mathematical enquiry into the causes of diseases, and the structure of bodies; and to shew the follies and weaknesses of the jargon introduced by Paracelsus, Helmont, and other chemical enthusiasts, who have obtruded upon the world the most airy dreams, and instead of enlightening their readers with explications of nature, have darkened the plainest appearances, and bewildered mankind in error and obscurity.

Boerhaave had now for nine years read physical lectures, but without the title or dignity of a professor, when, by the death of professor Hotten, the professorship of physick and botany fell to him of course.

On this occasion he asserted the simplicity and facility of the science of physick, in opposition to those that think obscurity contributes to the dignity of learning, and that to be admired it is necessary not to be understood.

*From The Edgar F. Smith Memorial Collection, University of Pennsylvania*

HERMAN BOERHAAVE

His profession of botany made it part of his duty to superintend the physical garden, which improved so much by the immense number of new plants which he procured, that it was enlarged to twice its original extent.

In 1714 he was deservedly advanced to the highest dignities of the university, and in the same year made physician of St. Augustin's hospital in Leyden, into which the students are admitted twice a week, to learn the practice of physick.

This was of equal advantage to the sick and to the students, for the success of his practice was the best demonstration of the soundness of his principles.

When he laid down his office of governor of the university in 1715, he made an oration upon the subject of "attaining to certainty in natural philosophy"; in which he declares, in the strongest terms, in favour of experimental knowledge, and reflects with just severity upon those arrogant philosophers, who are too easily disgusted with the slow methods of obtaining true notions by frequent experiments, and who, possest with too high an opinion of their own abilities, rather chuse to consult their own imaginations, than enquire into nature, and are better pleased with the charming amusement of forming hypotheses, than the toilsome drudgery of making observations.

The emptiness and uncertainty of all those systems, whether venerable for their antiquity, or agreeable for their novelty, he has evidently shewn; and not only declared, but proved, that we are intirely ignorant of the principles of things, and that all the knowledge we have is of such qualities alone as are discoverable by experience, or such as may be deduced from them by mathematical demonstration.

This discourse, filled as it was with piety, and a true sense of the greatness of the Supreme Being, and the incomprehensibility of his works, gave such offence to a professor of Franeker, who professed the utmost esteem for Des Cartes, and considered his principles as the bulwark of orthodoxy, that he appeared in vindication of his darling author, and spoke of the injury done him with the utmost vehemence, declaring little less than that the Cartesian system and the Christian must inevitably stand and fall together, and that to say we were ignorant of the principles of things, was not only to enlist among the Sceptics, but sink into Atheism itself.

So far can prejudice darken the understanding, as to make it consider precarious systems as the chief support of sacred and unvariable truth.

This treatment of Boerhaave was so far resented by the governors of his university, that they procured from Franeker a recantation of the invective that had been thrown out against him; this was not only complied with, but offers were made him of more ample satisfaction; to which he returned an answer not less to his honour than the victory he gained, "that he should think himself sufficiently compensated, if his adversary received no farther molestation on his account."

So far was this weak and injudicious attack from shaking a reputation not casually raised by fashion or caprice, but founded upon solid merit, that the same year his correspondence was desired upon Botany and Natural Philosophy by the Academy of Sciences at Paris, of which he was, upon the death of count Marsigli, in the year 1728, elected a member.

Nor were the French the only nation by which this great man was courted and distinguished, for two years after he was elected fellow of our Royal Society.

It cannot be doubted but, thus caressed and honoured with the highest and most publick marks of esteem by other nations, he became more celebrated in the university; for Boerhaave was not one of those learned men, of whom the world has seen too many, that disgrace their studies by their vices, and by unaccountable weaknesses make themselves ridiculous at home, while their writings procure them the veneration of distant countries, where their learning is known, but not their follies.

Not that his countrymen can be charged with being insensible of his excellencies till other nations taught them to admire him; for in 1718 he was chosen to succeed Le Mort in the professorship of chemistry; on which occasion he pronounced an oration "*De Chemia errores suos expurgante*," in which he treated that science with an elegance of style not often to be found in chemical writers, who seem generally to have affected not only a barbarous, but unintelligible phrase, and to have, like the Pythagoreans of old, wrapt up their secrets in symbols and aenigmatical expressions, either because they believed that mankind would reverence most what they least understood, or because they wrote not from benevolence but vanity, and were desirous to be praised for their knowledge, though they could not prevail upon themselves to communicate it.

In 1722, his course both of lectures and practice was interrupted by the gout, which, as he relates it in his speech after his recovery, he brought upon himself, by an imprudent confidence in the strength of his own constitution, and by transgressing those rules which he had a thousand times inculcated to his pupils and acquaintance. Rising in the morning before day, he went immediately, hot and sweating, from his bed into the open air, and exposed himself to the cold dews.

The history of his illness can hardly be read without horror: he was for five months confined to his bed, where he lay upon his back without daring to attempt the least motion, because any effort renewed his torments, which were so exquisite, that he was at length not only deprived of motion but of sense. Here art was at a stand, nothing could be attempted, because nothing could be proposed with the least prospect of success. At length having, in the sixth month of his illness, obtained some remission, he took simple medicines[6] in large quantities, and at length wonderfully recovered.

His recovery, so much desired, and so unexpected, was celebrated on Jan. 11, 1723, when he opened his school again with general joy and publick illuminations.

It would be an injury to the memory of Boerhaave not to mention what was related by himself to one of his friends, that when he lay whole days and nights without sleep, he found no method of diverting his thoughts so effectual as meditation upon his studies, and that he often relieved and mitigated the sense of his torments by the recollection of what he had read, and by reviewing those stores of knowledge which he had reposited in his memory.

This is perhaps an instance of fortitude and steady composure of mind, which would have been for ever the boast of the Stoick schools, and increased the reputation of Seneca or Cato. The patience of Boerhaave, as it was more rational, was more lasting than theirs; it was that *patientia Christiana* which Lipsius, the great master of the Stoical Philosophy, begged of God in his last hours; it was founded on religion, not vanity, not on vain reasonings, but on confidence in God.

In 1727 he was seized with a violent burning fever, which continued so long that he was once more given up by his friends.

From this time he was frequently afflicted with returns of his distemper, which yet did not so far subdue him, as to make him lay aside his studies or his lectures, till in 1726 he found himself so worn out that it was improper for him to continue any longer the professorships of botany and chemistry, which he therefore resigned April 28, and upon his resignation spoke a "*Sermo Academicus*," or oration, in which he asserts the power and wisdom of the Creator from the wonderful fabrick of the human body; and confutes all those idle reasoners, who pretend to explain the formation of parts, or the animal operations, to which he proves that Art can produce nothing equal, nor any thing parallel. One instance I shall mention, which is produced by him, of the vanity of any attempt to rival the work of God. Nothing is more boasted by the admirers of chemistry, than that they can, by artificial heats and digestion, imitate the productions of Nature. "Let all these heroes of science meet together," says Boerhaave; "let them take bread and wine, the food that forms the blood of man, and by assimilation contributes to the growth of the body: let them try all their arts, they shall not be able from these materials to produce a single drop of blood. So much is the most common act of Nature beyond the utmost efforts of the most extended Science!"

From this time Boerhaave lived with less publick employment indeed, but not an idle or an useless life; for, besides his hours spent in instructing his scholars, a great part of his time was taken up by patients which came, when the distemper would admit it, from all parts of Europe to consult him, or by letters which, in more urgent cases, were continually sent, to enquire his opinion, and ask his advice.

Of his sagacity, and the wonderful penetration with which he often discovered and described, at the first sight of a patient, such distempers as betray themselves by no symptoms to common eyes, such wonderful relations have been spread over the world, as, though attested beyond doubt, can scarcely be credited. I mention none of them, because I have no opportunity of collecting testimonies, or distinguishing between those accounts which are well proved, and those which owe their rise to fiction and credulity.

Yet I cannot but implore, with the greatest earnestness, such as have been conversant with this great man, that they will not so far neglect the common interest of mankind, as to suffer any of these circumstances to be lost to posterity. Men are generally idle, and ready to satisfy themselves, and intimidate the industry of others, by calling that impossible which is only difficult. The skill to which Boerhaave attained, by a long and unwearied observation of nature, ought therefore to be transmitted in all its particulars to future ages, that his successors may be ashamed to fall below him, and that none may hereafter excuse his ignorance by pleading the impossibility of clearer knowledge.

Yet so far was this great master from presumptuous confidence in his abilities, that, in his examinations of the sick, he was remarkably circumstantial and particular. He well knew that the originals of distempers are often at a distance from their visible effects; that to conjecture, where certainty may be obtained, is either vanity or negligence; and that life is not to be sacrificed, either to an affectation of quick discernment, or of crowded practice, but may be required, if trifled away, at the hand of the physician.

About the middle of the year 1737, he felt the first approaches of that fatal illness that brought him to the grave, of which we have inserted an account, written by himself Sept. 8, 1738, to a friend at London[6]; which deserves not only to be preserved as an historical relation of the disease which deprived us of so great a man, but as a proof of his piety and resignation to the divine will.

In this last illness, which was to the last degree lingering, painful, and afflictive, his constancy and firmness did not forsake him. He neither intermitted the necessary cares of life, nor forgot the proper preparations for death. Though dejection and lowness of spirit was, as he himself tells us, part of his distemper, yet even this, in some measure, gave way to that vigour which the soul received from a consciousness of innocence.

About three weeks before his death he received a visit at his country house from the Rev. Mr. Schultens, his intimate friend, who found him sitting with-out-door, with his wife, sister, and daughter: after the compliments of form, the ladies withdrew, and left them to private conversation; when Boerhaave took occasion to tell him what had been, during his illness, the chief subject of his thoughts. He had never doubted of the spiritual and immaterial nature of the soul; but declared that he had lately had a kind of experimental certainty of the distinction between corporeal and thinking substances, which mere reason and philosophy cannot afford, and opportunities of contemplating the wonderful and inexplicable union of soul and body, which nothing but long sickness can give. This he illustrated by a description of the effects which the infirmities of his body had upon his faculties, which yet they did not so oppress or vanquish, but his soul was always master of itself, and always resigned to the pleasure of its Maker.

He related with great concern, that once his patience so far gave way to extremity of pain, that, after having lain fifteen hours in exquisite tortures, he prayed to God that he might be let free by death.

Mr. Schultens, by way of consolation, answered, that he thought such wishes, when forced by continued and excessive torments, unavoidable in the present state of human nature; that the best men, even Job himself, were not able to refrain from such starts of impatience. This he did not deny; but said, "He that loves God, ought to think nothing desirable but what is most pleasing to the supreme goodness."

Such were his sentiments, and such his conduct, in this state of weakness and pain: as death approached nearer, he was so far from terror or confusion, that he seemed even less sensible of pain, and more cheerful under his torments, which continued till the 23d day of September 1738, on which he died, between four and five in the morning, in the 70th year of his age.

Thus died Boerhaave, a man formed by nature for great designs, and guided by religion in the exertion of his abilities. He was of a robust and athletic constitution of body, so hardened by early severities, and wholesome fatigue, that he was insensible of any sharpness of air, or inclemency of weather. He was tall, and remarkable for extraordinary strength. There was in his air and motion something rough and artless, but so majestick and great at the same time, that no man ever looked upon him without veneration, and a kind of tacit submission to the superiority of his genius.

The vigour and activity of his mind sparkled visibly in his eyes; nor was it ever observed, that any change of his fortune, or alteration in his affairs, whether happy or unfortunate, affected his countenance.

He was always cheerful, and desirous of promoting mirth by a facetious and humorous conversation; he was never soured by calumny and detraction, nor ever thought it necessary to confute them; "for they are sparks," said he, "which if you do not blow them, will go out of themselves."

Yet he took care never to provoke enemies by severity of cen-

sure, for he never dwelt on the faults or defects of others, and was so far from inflaming the envy of his rivals by dwelling on his own excellencies, that he rarely mentioned himself or his writings.

He was not to be overawed or depressed by the presence, frowns, or insolence of great men, but persisted on all occasions in the right, with a resolution always present and always calm. He was modest, but not timorous, and firm without rudeness.

He could, with uncommon readiness and certainty, make a conjecture of men's inclinations and capacity by their aspect.

His method of life was to study in the morning and evening, and to allot the middle of the day to his publick business. His usual exercise was riding, till, in his latter years, his distempers made it more proper for him to walk: when he was weary, he amused himself with playing on the violin.

His greatest pleasure was to retire to his house in the country, where he had a garden stored with all the herbs and trees which the climate would bear; here he used to enjoy his hours unmolested, and prosecute his studies without interruption.

The diligence with which he pursued his studies, is sufficiently evident from his success. Statesmen and generals may grow great by unexpected accidents, and fortunate concurrence of circumstances, neither procured nor foreseen by themselves: but reputation in the learned world must be the effect of industry and capacity. Boerhaave lost none of his hours, but, when he had attended one science, attempted another: he added physick to divinity, chemistry to the mathematicks, and anatomy to botany. He examined systems by experiments, and formed experiments into systems. He neither neglected the observations of others, nor blindly submitted to celebrated names. He neither thought so highly of himself as to imagine he could receive no light from books, nor so meanly as to believe he could discover nothing but what was to be learned from them. He examined the observations of other men, but trusted only to his own.

Nor was he unacquainted with the art of recommending truth by elegance, and embellishing the philosopher with polite literature: he knew that but a small part of mankind will sacrifice their pleasure to their improvement, and those authors who would find many readers, must endeavour to please while they instruct.

He knew the importance of his own writings to mankind, and lest he might by a roughness and barbarity of style, too frequent among men of great learning, disappoint his own intentions, and make his labours less useful, he did not neglect the politer arts of eloquence and poetry. Thus was his learning at once various and exact, profound and agreeable.

But his knowledge, however uncommon, holds, in his character, but the second place; his virtue was yet much more uncommon than his learning. He was an admirable example of temperance, fortitude, humility, and devotion. His piety, and a religious sense of his dependance on God, was the basis of all his virtues, and the principle of his whole conduct. He was too sensible of his weakness to ascribe any thing to himself, or to conceive that he could subdue passion, or withstand temptation, by his own natural power; he attributed every good thought, and every laudable action, to the Father of goodness. Being once asked by a friend, who had often admired his patience under great provocations, whether he knew what it was to be angry, and by what means he had so entirely suppressed that impetuous and ungovernable passion? he answered, with the utmost frankness and sincerity, that he was naturally quick of resentment, but that he had, by daily prayer and meditation, at length attained to this mastery over himself.

As soon as he rose in the morning, it was, throughout his whole life, his daily practice to retire for an hour to private prayer and meditation; this, he often told his friends, gave him spirit and vigour in the business of the day, and this he therefore commended as the best rule of life; for nothing, he knew, could support the soul in all distresses but a confidence in a Supreme Being, nor can a steady and rational magnanimity flow from any other source than a consciousness of the divine favour.

He asserted on all occasions the divine authority, and sacred efficacy of the holy scriptures; and maintained that they alone taught the way of salvation, and that they only could give peace of mind. The excellency of the Christian religion was the frequent subject of his conversation. A strict obedience to the doctrine, and a diligent imitation of the example of our Blessed Saviour, he often declared to be the foundation of true tranquillity. He recommended to his friends a careful observation of the precept of Moses concerning the love of God and man. He worshipped God as he is in himself, without attempting to enquire into his nature. He desired only to think of God, what God knows of himself. There he stopped, lest, by indulging his own ideas, he should form a Deity from his own imagination, and sin by falling down before him. To the will of God he paid an absolute submission, without endeavouring to discover the reason of his determinations; and this he accounted the first and most inviolable duty of a Christian. When he heard of a criminal condemned to die, he used to think, who can tell whether this man is not better than I? or, if I am better, it is not to be ascribed to myself, but to the goodness of God.

Such were the sentiments of Boerhaave, whose words we have added in the note.[5] So far was this man from being made impious by philosophy, or vain by knowledge, or by virtue, that he ascribed all his abilities to the bounty, and all his goodness to the grace of God. May his example extend its influence to his admirers and followers! May those who study his writings imitate his life! and those who endeavour after his knowledge aspire likewise to his piety!

He married, September 17, 1710, Mary Drolenveaux, the only daughter of a burgo-master of Leyden, by whom he had Joanna Maria, who survives her father, and three other children who died in their infancy.

The works of this great writer are so generally known, and so highly esteemed, that, though it may not be improper to enumerate them in the order of time in which they were published, it is wholly unnecessary to give any other account of them.

He published in 1707, "*Institutiones Medicae*," to which he added in 1708, "*Aphorismi de cognoscendis & curandis morbis.*"

1710, "*Index stirpium in horto academico.*"

1719, "*De materia medica, & remediorum formulis liber*"; and in 1727 a second edition.

1720, "*Alter index stirpium,*" &c. adorned with plates, and containing twice the number of plants as the former.

1722, "*Epistola ad cl. Ruischium, qua sententiam Malpighianam de glandulis defendit.*"

1724, "*Atrocis nec prius descripti morbi historia illustrissimi baronis Wassenariae.*"

1725, "*Opera anatomica & chirurgica Andreae Vesalii,*" with the life of Vesalius.

1728, "*Altera atrocis rarissimique morbi marchionis de Sancto Albano historia.*"

"*Auctores de lue Aphrodisiaca, cum tractatu praefixo.*"

1731, "*Aretaei Cappadocis nova editio.*"

1732, "*Elementa chemiae.*"

1734, "*Observata de argento vivo, ad reg. soc. & acad. scient.*"

These are the writings of the great Boerhaave, which have made all encomiums useless and vain, since no man can attentively pursue them without admiring the abilities, and reverencing the virtue of the author.

## MOTION PICTURE FILM

"The Evolution of the Oil Industry," a 16-mm. sound picture, is now available from the Bureau of Mines Experiment Station, 4800 Forbes St., Pittsburgh, Pennsylvania.

# Industrial and Military Explosives[1]

R. W. CAIRNS[2] *Hercules Powder Company, Wilmington, Delaware*

IT HAS become so customary to emphasize the destructive power of explosives, that few people realize the fact that modern industrial explosives are the basis for some of our most important constructive efforts. Explosives provide stored energy in a convenient usable form; the value of explosives lies in their ability to do work, particularly under conditions where other forms of energy are not readily applicable. Whether that work is expended in shattering work as in quarrying or metal mining, in moving earth as in road making and other construction work, or in breaking down coal, explosives may be designed to give controlled and effective results.

There are so many popular fallacies with respect to explosives, and the subject is so unfamiliar to the average person, that a comparison with other more familiar sources of energy might serve as the most effective form of introduction. Let us take coal as an example; the heat liberated by the combination of this fuel with the oxygen in air (a chemical reaction called oxidation) may be put to useful purposes, as in a steam engine. There the action of heat on steam causes the latter to expand and move a piston which can perform useful work. While other devices function in different ways, for example, steam or water turbines, internal combustion engines, and electric motors, the common property which characterizes all machines is their ability to convert stored energy (potential energy) into useful work.

The factor which distinguishes explosives from other sources of potential energy is their ability to perform useful tasks without the intervention of a special machine. Unlike coal and other fuels, explosives require no oxygen from the air, because an adequate supply of that element is contained within the explosive compound. Thus, they may be used under conditions where no air is present, as under water and in deep boreholes in rock.

When an explosion occurs, great quantities of hot gases are rapidly generated. It is the force of expansion of these gases which, like the steam in an engine cylinder, exerts pressure on the surroundings, causing motion of material so as to relieve the intense pressure. In both cases, there is a release of the pent-up potential energy in either the hot gases or steam. This reappears as kinetic energy of motion (on the one hand, of earth, rock, or coal, and on the other hand, of the piston). In the case of high explosives, the rate of pressure development and the magnitude of the maximum pressure are both at least a thousand times greater than in the cylinder of a steam engine. It is this speed and intensity of action which accounts for the adaptability and usefulness of explosives.

Charges of a few hundred pounds of high explosive, when properly loaded in well-placed boreholes, will break up and move many tons of rock into position for easy removal. This process may consist of a frequently recurring series of small steps, as when a tunnel is driven through solid rock, or it may be carried out on a grand scale in large quarries, where frequently as much as 50,000 pounds of dynamite is shot in a single explosion, yielding hundreds of thousands of tons of broken rock ready for the steam shovel. In some instances, hundreds of thousands of pounds of explosive have been shot at one time. In any case, the details of the process are essentially the same; boreholes or chambers of sufficient size and with carefully planned position and depth are first drilled into the rock mass; then the explosive chosen for the specific purpose is loaded into the boreholes or chambers, as shown, in calculated quantities and arrangements are made for firing the charges. Confinement of the charge is usually provided by filling the partially loaded boreholes with crushed rock or other materials to increase the efficiency of the explosive. The final step is the actual firing of the charge, which may be done either electrically, by a black powder safety fuse, or by a detonating fuse.

LARGE LIMESTONE QUARRY BLAST

In this blast, 125,000 tons of limestone were brought down by 26,500 pounds of dynamite. The uniform results were obtained through accurate calculations of rock burdens and explosive charges.

Before we discuss further details concerning specific types of explosives and the uses to which they are put, some basic principles must be explained. The most important properties of explosives, from a practical viewpoint, are stability, strength, and manner of decomposition or explosion. These properties will be dealt with in the following section.

[1] Publication rights reserved except by permission of author.
[2] Director of Hercules Experiment Station.

## GENERAL PROPERTIES OF EXPLOSIVES

### *Stability*

In the popular mind, explosives are extremely touchy substances, liable to explode on the slightest provocation, and therefore extremely dangerous to handle.

DRILLING BOREHOLE (*Upper left*) AND LOADING EXPLOSIVES (*Lower left*) INTO THESE HOLES IN A LARGE OPEN-CUT COPPER MINE

While no one in his right senses would care to handle explosives except with extreme caution, in view of their potential power to cause damage, conventional explosive compounds are generally very stable. Under proper conditions of storage, it is possible to store them for years without serious deterioration. Furthermore, if reasonable precautions are observed and the users are experienced, the handling and transportation of explosives may be remarkably free from accidents. As an outstanding example, the transportation of explosives by railroads has been free from fatalities and serious accidents of any kind for fourteen years, during which time over seven and a half billion pounds of industrial explosives have been shipped. On the other hand, carelessness with explosives is likely to terminate suddenly in serious consequences. The energy contained in a cartridge of dynamite is about equal to the energy of motion in an automobile traveling at seventy-five miles per hour, and the amount of localized damage its accidental explosion could cause is equivalent to that resulting from a head-on collision of an automobile at this speed.

Everyone is familiar with the charring of many types of common materials, such as paper, sugar, or bread, at fairly low temperatures. Usually, the compounds that make up such materials, if they are organic in nature (that is, complex compounds of carbon), will exhibit a detectable amount of decomposition at about 150°C. In this respect the commoner explosive compounds are no exception. The difference is that most compounds absorb heat when they break down, whereas explosive compounds produce large quantities of heat; as a consequence, when explosives are raised to elevated temperatures, heat is evolved faster than it can be dissipated, self-heating occurs, the decomposition speeds up, and this cumulative process leads to an extremely rapid decomposition known as explosion. The higher the initial temperature, the more rapidly explosion will develop. At from 200°C. to 300°C., most explosives will explode instantly.

### *Strength*

Misunderstandings as to the strength of explosives lead to all sorts of fantastic claims and beliefs concerning them. While there is no reason to belittle the intensity of explosive effects in the immediate vicinity of an explosion, the strength of an explosive is really quite small compared to the energy content of other forms of stored energy. When coal or fuel oil is burned, it combines with three to four times its weight of oxygen, absorbed from the air. In an explosive no external oxygen is consumed, the necessary amount already being present in combined form. In view of the similarity of the oxidation reactions occurring in either case, it is not surprising that the energy developed by a pound of a powerful explosive is only about one-fifth as great as that obtainable by burning a pound of coal, since in the latter case one must take into account the fact that a total weight of almost five pounds of coal and oxygen are reacting.

While it is possible to make explosives which do not depend on oxidation for their energy production, practically all present-day explosives for both industrial and military use contain large amounts of available oxygen, as well as other elements, such as carbon and hydrogen, which can combine with this oxygen and release large amounts of energy. In this combination, large volumes of carbon dioxide and water vapor are released. The high pressures thus produced and their speed of production account for the violent action of explosives. Oxidation reactions are generally very rich in energy. For thousands of years man has depended on the burning (or oxidation) of various types of fuels to keep him warm and do his work. Even today we still use the fuels which were available and used many centuries ago, with little change save in the development of more efficient combustion methods. With our present wide knowledge of chemical reactions, and the absence of practical types of reactions yielding much higher energies than oxidation, it is unlikely that significant increases will be obtained in the strength of explosives until some entirely unknown source of stored energy becomes available. When that time comes, the application of such knowledge to explosives would be quite overshadowed by its tremendous importance for ordinary fuel uses.

*Manner of Decomposition or Explosion*

Although people commonly exaggerate both the instability and the strength of explosives, the speed of explosion is apt to stagger the imagination. Even in the case of black powder, which is a relatively slow explosive, the time for complete combustion of a reasonably large charge amounts to only a few thousandths of a second. However, a cartridge of dynamite decomposes completely in a few millionths of a second. If one were to photograph the intense light that is emitted when dynamite explodes, using a high-speed motion-picture camera with a film speed of 100,000 frames per second, only one frame would be exposed, the others being almost completely blank. Thus, even the fastest of modern high-speed motion-picture cameras is too slow to show what happens during such an explosion, and only very special continuous-motion cameras can be used.

This extraordinary speed can give rise to some very surprising effects. For instance, a photographic record of the light emitted during the explosion will produce on the film an image of the dynamic cartridge down to the minutest detail. Even the irregularities in the folds of the paper wrappings will be visible, as well as the granular structure of the explosive. The explanation of this effect is that the explosion was complete before the explosion products had time to expand and disrupt the paper wrapper. In effect, the explosive was completely converted from a solid stable material into gaseous products in the original shape and volume of the charge, at enormous pressure, before any appreciable expansion occurred. It is this remarkable velocity of conversion of the explosive into explosion products that characterizes high explosives. More will be said of this property later.

*Burning or Combustion versus Detonation*

Although all explosives are capable of very rapid decomposition, there are marked differences between the various types and their explosive effects. The contrast in speed of explosion has already been pointed out in the case of black powder and dynamite. The characteristic mode of explosion of black powder is called combustion or burning. The characteristic process for dynamite is called detonation. Many explosives can either burn or detonate, depending on the particular conditions. In all cases, explosions may be classified as one of these two basic types.

An explosive burns in much the same manner as a fuel, but with the difference that no external oxygen or air is required. Consequently, many explosives will burn under water once ignition has occurred. A point of similarity with fuels is that a finely powdered explosive will burn faster than a coarse one. The burning is confined to the surface of the particles, and the smaller they are the more rapidly they will be consumed. This behavior is like the rapid burning of paper compared to the slowness of a log fire.

Although the combustion of an explosive is very fast compared to ordinary processes, it is slow enough so that the gases produced in the explosion expand as rapidly as they are formed, and exert a uniform pressure against any obstacles. For this reason, it is possible to use a burning explosive as a means to fire a projectile from a gun. A charge of black powder may thus be loaded behind a bullet in a rifle barrel, and its ignition, followed by rapid combustion, will generate gases which push against the bullet and eject it at high speed from the muzzle. Because the pressure builds up gradually, and slowly enough to allow the bullet to move out and release the pent-up gases, the gun is not ruptured, and many shots may be fired from the same gun.

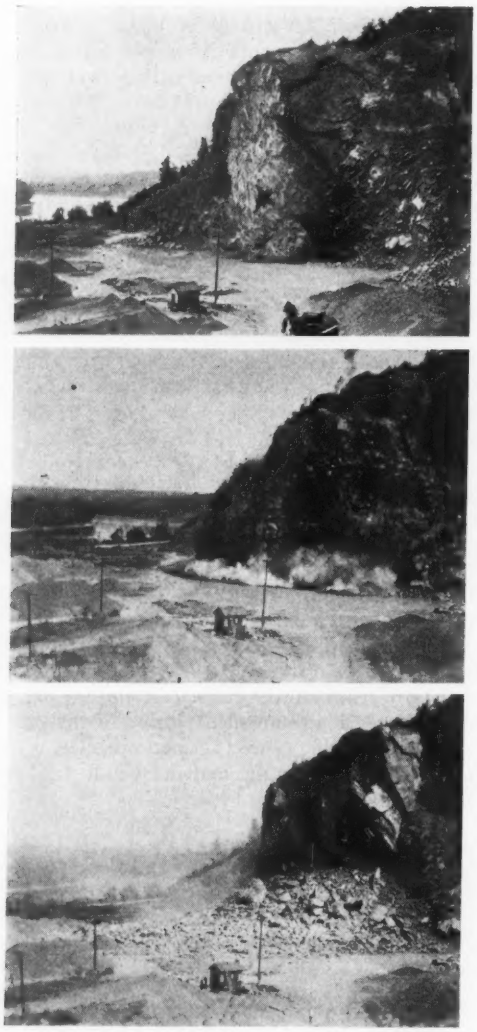
Another striking fact about burning explosives is that combustion is strongly affected by the pressure of the product gases. The burning speed is directly proportional to the pressure. In a gun, this pressure build ups to magnitudes of ten to fifty thousand pounds per square inch and fast burning occurs. The same explosive burns much more slowly in the open and without appreciable noise.

In contrast to combustion, the process we call detonation is very much more rapid and violent. As already pointed out, the speed is at least a thousand times as great. On account of this difference, the explosion gases do not have an opportunity to expand until the conversion of the explosive is practically complete. Therefore, terrific pressures are generated and no material will stand close contact without being shattered. Detonating explosives are useless for propelling projectiles from guns. Attempts to apply them would result in violent explosion of the gun barrels. This shattering power, termed brisance, is a very useful property in blasting, and most industrial explosives are of the detonating type.

EXPLOSION PHOTOGRAPH OF A DYNAMITE CARTRIDGE
Taken with a moving-film camera specially developed by the Hercules Powder Company

The tremendous speed of detonation greatly lessens the effect that a confining vessel or container may exert. A high explosive (so-called because of its ability to explode or detonate with high velocity) can be detonated in the open, *i. e.*, with the bare charge in a compact

shape but with no container, and its violence will be practically undiminished. Dynamite is customarily packed into paper shells. The velocity of explosion is practically the same when the dynamite is fired on the surface of the ground as when it is embedded in the solid rock. This action accounts for the common saying that "dynamite shoots down, while black powder shoots upwards." If a stick of dynamite is laid on a boulder and exploded, it will split the stone, because of the very intense localized pressure built up in the very fast explosion. When a charge of black powder is burned on a rock, nothing happens but a flare and a puff of smoke that is ejected up into the air. The explosion or combustion in open air is slow enough to avoid building up any high pressure at any time.



A SUCCESSFUL BLAST IN A TRAP ROCK QUARRY
*Top:* Quarry face before blast
*Middle:* 9575 pounds of dynamite at work
*Bottom:* 44,500 tons of trap rock brought down by the blast

Unlike combustion, detonation is not confined to the surface of the explosive particles. The decomposition of the explosive to a gas occurs as a wave, commencing at a point and spreading with high speed in all directions, consuming everything in its path. If the dynamite cartridge is detonated at one end, this wave of detonation passes at a speed of as much as several miles per second toward the opposite end of the cartridge. At the surface of the explosive a spreading wave of intense shock is produced, and this progresses away from the charge at high speed, shattering the rock, or whatever is in its path. Behind this shock wave come the pent-up explosion gases which push the rock aside in seeking to escape its confining action.

Finally, we can contrast burning and detonation according to the methods required to start these processes. Burning, as the name implies, can be started by a flame, either from a match or a black powder fuse. Detonation generally occurs as a result of a powerful shock or impact. It would be possible to detonate some types of dynamite by a hammer blow, but this method is not convenient, nor is it safe. Since detonating explosives themselves generate an intense shock, it is obvious that one explosive charge can serve to detonate an adjacent charge of the same or another explosive. For this reason, it is possible to make use of small charges of a special type of high explosive known as initiating or priming explosives. Priming explosives have the peculiar ability to detonate when they are ignited by a flame. Combustion occurs first, but the burning is so intense that a detonation wave is produced, and the remaining charge detonates violently.

Now that the important properties of explosives have been brought out in a completely general way, the next section will be devoted to a description of several important examples of explosives.

## IMPORTANT TYPES OF EXPLOSIVES

### *Black Powder*

Historically, this explosive was the first known to man; it was discovered centuries ago by the Chinese, and independently by Roger Bacon in England in the thirteenth century. For several centuries it was used only in warfare, chiefly for propelling bullets or cannon balls from guns. Not until the eighteenth century did it come into active use for constructive purposes such as blasting rock and coal.

In composition this explosive consists of a mixture containing principally saltpeter (potassium nitrate, or in more recent times the cheaper sodium nitrate) together with charcoal and sulfur. These ingredients are thoroughly incorporated by milling in a moist condition, pressed into a hard cake, granulated, and dried. The granules are glazed with graphite to make them free-flowing for ease in packing and handling. The black powder is graded as to size of granules.

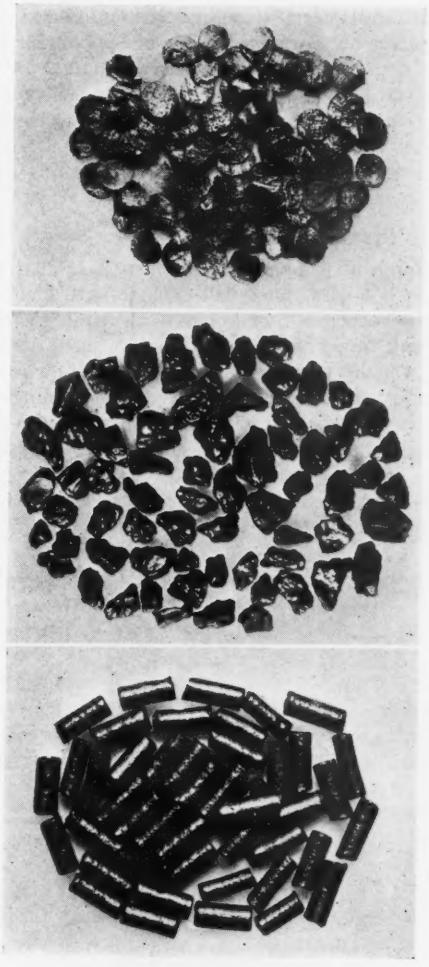
As would be expected from the preceding section, the finer grains are faster burning (for rifle use) and the coarser are slower burning (for blasting coal). The explosive reaction takes place when the charcoal and sulfur burn and are oxidized by the oxygen in saltpeter. Carbon monoxide, carbon dioxide, nitrogen, and sulfur dioxide are formed, as well as numerous solid compounds. The presence of the latter in the explosion products causes dense black smoke and is responsible for fouling of guns. The slow burning of black powder produces a relatively slow flame which makes its use in coal mines dangerous whenever flammable mine gases are present. Since the advent of smokeless powder and dynamite, black powder has been gradually displaced from both uses, because of the superior quality of the latter explosives.

*Smokeless Powder*

Although the discovery of nitrocellulose (more correctly called cellulose nitrate), the principal ingredient of smokeless powder, is usually credited to the German, Christian Friedrich Schönbein, in 1845, several decades passed before it was used successfully, in place of black powder, as a propellant in guns. Nitrocellulose is obtained by treating cotton or wood pulp (two forms of cellulose) with a mixture of strong nitric and sulfuric acids. By this process, nitrate groups are introduced into the cellulose molecule (which originally contained carbon, hydrogen, and some oxygen). These nitrate groups act in the same way as the saltpeter in black powder; during combustion they give up oxygen which burns the carbon and hydrogen to form carbon monoxide, carbon dioxide, and water vapor, as well as nitrogen, at high temperatures. When first produced, nitrocellulose possesses the same physical form as the original fibrous cellulose. This material is so fine and burns so rapidly that it is not suitable for ammunition. However, the fibers can be dissolved in various solvents such as acetone or a mixture of ethyl alcohol and ethyl ether. The latter solution is usually termed collodion, and has the familiar use of sealing cuts or abrasions. Different grades of partially nitrated cellulose have varied uses and forms; a compound of camphor and nitrocellulose is known as celluloid. Pyroxylin is another name for a solid nitrocellulose plastic which is formed into many familiar and useful articles.

In the manufacture of smokeless powder, nitrocellulose is partially dissolved in the above solvents, with or without other explosive ingredients. It can then be extruded into macaroni-like rods or tubes. These are cut into flakes or cylinders and the solvent is removed by evaporation. The resulting grains are solid, hard, and horny, ranging from a few thousandths of an inch thick up to an inch or even larger depending on the size of the gun for which the smokeless powder is designed. Incidentally, the term "powder," when applied to explosives, is rather misleading, since most explosives are not powder-like in form. The term was adopted because of the appearance of early types of black powder, and later came to be applied to many types of explosives.

There are two general types of smokeless powder, designated as single-base and double-base. Single-base smokeless powder contains no explosive other than nitrocellulose. Double-base smokeless powder contains another explosive as well, usually nitroglycerin. Other explosive ingredients, such as di- or tri-nitrotoluene (TNT), may be used with nitrocellulose. The latter types of powders are given the designation "FNH," an abbreviation for "flashless, nonhygroscopic," which refers to their outstanding properties in military ammunition.



THREE TYPES OF POWDER
*Top:* Smokeless powder for shotgun
*Middle:* Black powder for shotgun
*Bottom:* Smokeless powder for rifle
Magnification approximately 3.5×

In the burning of smokeless powder, little solid residue is left behind to foul the gun. Furthermore, the grain size is subject to accurate control, which permits

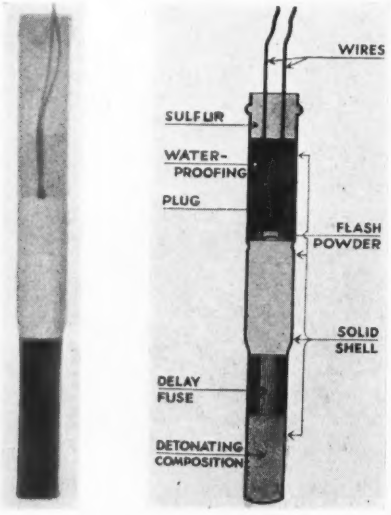
very uniform burning speeds. Consequently, much greater accuracy of fire is possible than when black powder is used. Its greater strength also permits greater range of fire. The term "smokeless" is only a relative one. In small arms, smoke is very light, in contrast to the dense smoke developed by black powder. However, the firing of large guns is always accompanied by large volumes of smoke.

The characteristic manner of explosion of smokeless powder is combustion, and ignition is usually obtained by a percussion primer, which produces a flame when struck by the hammer of a gun. This type of primer is analogous to a match in composition and action and is quite small in size. Although nitrocellulose in fibrous form is highly flammable and usually decomposes by burning, it can also detonate and in fact was used as a high-explosive charge for mines during the first World War. Even smokeless powder can be made to detonate under special conditions. However, its properties are such as to make it much better suited to use as a propelling charge for guns than as a high explosive.

*Priming Explosives*

Although all explosives will burn if ignited with a flame or hot wire, some will explode with greater violence than others. Small charges of priming explosives burn with rapidly increasing violence until detonation occurs, usually within a few thousandths of a second.

Mercury fulminate was the first priming explosive, discovered in 1800 by an Englishman named Edward Howard. Although it was used exclusively in




MODERN DELAY ELECTRIC BLASTING CAP
*Left:* X-ray photograph
*Right:* Diagram

percussion primers and blasting caps for over a century, other more efficient and less costly priming explosives are now used. Examples of these are diazodinitrophenol, a complex organic compound related in structure to picric acid, an important drug for treating burns, and lead azide, a compound composed only

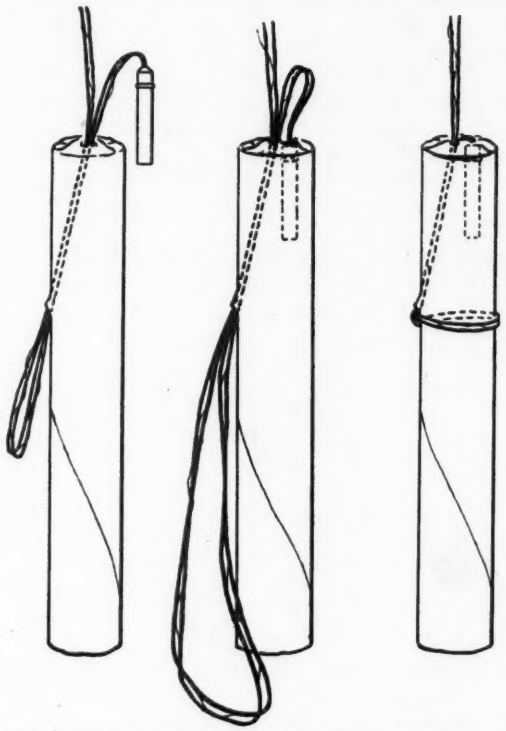


ILLUSTRATION OF THE METHOD OF PRIMING A CARTRIDGE OF DYNAMITE WITH AN ELECTRIC BLASTING CAP

of lead and nitrogen. The full potentialities of priming explosives were not realized until the invention of the blasting cap, in 1864, by Alfred Nobel, founder of the Nobel prize. A blasting cap consists of a small metal cylinder containing a few grains of such an explosive. The cap is inserted into a cartridge of dynamite which is to be fired. Ignition of the cap by the flame from a black powder fuse or by electrical means causes its explosion; the metal tube is shattered into thousands of minute fragments and the sudden shock causes the detonation of the adjacent charge of dynamite.

*Nitroglycerin and Dynamite*

Nitroglycerin (glyceryl trinitrate), made by the action of nitric acid on glycerin, was a laboratory curiosity for many years after its discovery in 1847 by Ascanio Sobrero in Italy. Alfred Nobel saw its possible usefulness as a blasting explosive, but it was only after great difficulty that he made its use practical, about twenty years later. By itself nitroglycerin is difficult to handle. Being a liquid, it will leak from containers and spread out in a thin layer, in which condition it will detonate on the slightest blow. Early attempts to use the liquid were frequently disastrous, and its use was therefore discouraged. Nobel, however, found that the

liquid could be readily absorbed in kieselguhr, a fine absorbent mineral substance. The mixture, which he called dynamite, could be stored and handled in large quantities without any serious hazards. He also discovered that when nitrocellulose was dissolved in nitroglycerin a tough, rubbery mass resulted, which was useful in under-water blasting. This product he called blasting gelatin. With an absorbent in the formulation, the plastic product is known as gelatin dynamite.

Nobel recognized that his nitroglycerin explosives could explode in two different ways, either by burning or by detonation. Only in the latter case is the maximum efficiency obtained, and after experimenting with many possibilities he finally invented the blasting cap as a safe and effective method for detonating a high explosive. Mercury fulminate was the priming explosive he used.

At the present time, dynamites are much more varied in composition than at the time of Nobel. Kieselguhr, as an absorbent for nitroglycerin, has been entirely replaced by active ingredients which contribute to the explosion. Kieselguhr acted as an inert filler, and reduced the strength of the dynamite. A mixture of an absorbent fuel, such as wood pulp, with an oxidizing salt, such as sodium nitrate, will absorb the nitroglycerin, and at the same time contribute to the heat and energy developed by the explosion of the dynamite. A variety of such combustible absorbents are used.

The cheapness and availability of ammonium nitrate has led to its widespread use in dynamites. This salt is explosive in the pure state, but very difficult to detonate; when mixed with nitroglycerin it explodes readily and with great power. Dynamites containing ammonium nitrate are widely used for blasting purposes and this ingredient constitutes about 40 per cent of all industrial explosives used.

Ammonium nitrate is particularly appropriate for application in coal-mining explosives. Although ammonium nitrate dynamites are usually quite powerful, they develop a lesser amount of heat during explosion than high nitroglycerin dynamites. They are therefore less likely to ignite the flammable vapors or gases sometimes encountered in coal mines. Explosives that are particularly suitable for application in "gassy" mines are certified as permissible for such use by the U. S. Bureau of Mines. Our modern effective and economical permissible explosives are a valuable contribution of explosives research to industrial progress and the advancement of safety in the mining of coal.

Since dynamites are put to a wide variety of uses, such as breaking rock and coal, digging ditches, shooting stumps, moving earth, settling "fill" in swamps, and demolishing old buildings, many types must be produced, with special properties to fit the specific needs. Extensive research and development have led to great advances in this field; by proper selection and application of modern dynamites, almost any heavy job similar to those above may be done quickly, economically, and efficiently by explosives.

BUGGY USED FOR TRANSPORTING NITROGLYCERIN IN A DYNAMITE PLANT
Note the heavy earthen barricade which surrounds the storage building.

*Military High Explosives*

Fundamentally, explosives for military use are similar to ordinary commercial explosives. Priming methods and the way in which explosion occurs are identical. As in other applications of high explosives, there are certain specialized requirements. An explosive which can be loaded into a shell and fired from a gun, without exploding until the shell strikes the target, must of necessity be fairly stable to shock. Other requirements of high strength, stability under all kinds of adverse weather conditions, and high density definitely limit the types which can be used. To fit all of these requirements, one of the best selections has been trinitrotoluene (TNT), a compound prepared by nitration of toluene, a substance derived from coal tar. This explosive, usually mixed with ammonium nitrate, is the principal bursting charge used in shells and bombs, and is used as well for mines and as a military demolition explosive.

In conclusion, it should be emphasized that the modern explosives industry has operated with a remarkable safety record. Through careful planning, and in many cases through bitter experience, great hazards have been brought under control. In the hands of experts, explosives may be used with much security. In the hands of the amateur, whether he be reckless or simply uninformed, explosives are and always will be dangerous. Even a blasting cap can cause the most serious consequences if misused. Intelligence in application will, however, make explosives our ever-willing and useful servants.

# The 1940–1941 College Chemistry Testing Program

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## THE FUNCTION OF THE TESTING PROGRAM

EACH year since 1935, the Committee on Examinations and Tests of the Division of Chemical Education, in collaboration with the Coöperative Test Service, has provided a test in general chemistry. The results of the testing program have been reported annually.[1] The function of the report is not merely to provide with the statistical data those who participated in the program, but also to analyze the data and make interpretations which would be of interest to all chemistry teachers. As the data accumulate, they would permit one to draw more definite conclusions on a number of educational problems. Moreover, the report attempts to appraise the entire program and to suggest ways in which it may be improved so that it may become more useful to an increasing number of chemistry teachers.

The function of the testing program has been discussed by Hendricks and Frutchey[2] and by the authors of the previous reports. In a conference held at the University of Chicago, June 21 to 27, 1941, in which the seven members of the committee and twelve other interested teachers participated, the functions of the testing program were considered in some detail. The following is a comprehensive summary of the functions, which met with general approval of the members of the conference.

1. To provide nationwide, comprehensive, and reliable standards
   - (*a*) For comparison of individuals with other members of their class or with national standards. These comparisons may be used for: grading purposes; placement of entering students; placement of transfer students; advising students in their courses by spotting superior students, discovering strengths and weaknesses of students, etc.
   - (*b*) For comparison of classes from year to year, thus helping to maintain or improve standards
   - (*c*) For comparison of different types of classes, *e. g.*, engineering classes vs. home economics, day classes vs. evening classes, etc.
   - (*d*) For comparison of schools with other schools under similar circumstances, *e. g.*, junior colleges vs. other junior colleges, etc.
   - (*e*) For comparison of schools with all the schools of the nation
   - (*f*) For comparison of instructors in the same school or school system, for the purpose of promotion (it is recognized, however, that there are serious dangers of misuse of the test for this purpose)
2. To provide an instrument to measure the absolute achievement
   - (*a*) Of individuals, groups, or schools on the test as a whole, giving some objective information on the degree of success of chemistry instruction
   - (*b*) Of all groups on different portions of the test, or even on individual items giving information on the relative difficulty of the various aspects of chemistry
3. To stimulate research in
   - (*a*) The clarification of the objectives of chemistry instruction
   - (*b*) The development of better educational measuring instruments
   - (*c*) The study of educational problems, by providing a more accurate instrument by which achievement may be measured

It is fully recognized that the program can be effective only in so far as the teachers in the various colleges have common objectives, and only to the degree to which these objectives are measured by the tests. It cannot be too strongly emphasized that in making the comparisons suggested above, one should bear in mind that the objectives of the various teachers might vary widely and that the tests thus far developed measure only a limited number of objectives. The program can become more effective by a coöperative effort of the teachers to clarify and make known their objectives, and by an effort on the part of those constructing the test to write items which measure other important objectives which are not now tested.

It is reassuring that a considerable fraction of the chemistry teachers have found these tests useful. The growth of the program is shown in Tables 1 and 2.

TABLE 1

COÖPERATIVE CHEMISTRY TEST DISTRIBUTION BY YEARS

| *Year* | *1935–36* | *1936–37* | *1937–38* | *1938–39* | *1939–40* | *1940–41* |
|---|---|---|---|---|---|---|
| Test recommended in programs* | 7,565 | 18,734 | 19,747 | 19,997 | 19,409 | 19,172 |
| Total tests distributed—all forms | 10,564 | 25,208 | 24,100 | 25,947 | 25,722 | 25,750 |
| QUALITATIVE ANALYSIS | | | | | | |
| Total tests distributed | | | | 2,140 | 2,584 | 2,390 |

* The form of the Coöperative Chemistry Test for College Students recommended for each program is as follows: 1935–36, Form 1936, Tests I, II, and C; 1936–37, Form 1937, Test C; 1937–38, Form 1938; 1938–39, Form 1939; 1939–40, Form 1940; 1940–41, Form 1941. The form of the Coöperative Chemistry Test in Qualitative Analysis recommended for each program is as follows; 1938–39, Form P; 1939–40, Form Q; 1940–41, Form Q. For a description of these tests, consult the 1942 Catalog, Coöperative Test Service, 15 Amsterdam Avenue, New York City.

A glance at these tables shows that the interest in these tests has reached a steady state. Foster finds that the tests serve primarily the small colleges, and advances some reasons[3] that might explain why the larger schools have not used the tests extensively. To

[1] (*a*) "The 1935-36 college chemistry testing program," J. CHEM. EDUC., **14**, 229 (1937); (*b*) PHELAN, "The 1936–1937 college chemistry testing program," *ibid.*, **14**, 587 (1937); (*c*) REED, "The 1937–1938 college chemistry testing program," *ibid.*, **16**, 184 (1939); (*d*) MARTIN, "The 1938–1939 college chemistry testing program," *ibid.*, **17**, 70 (1940); (*e*) FOSTER, "The 1939–1940 college chemistry testing program," *ibid.*, **18**, 159 (1941).

[2] HENDRICKS AND FRUTCHEY, "Uses of examinations," J. CHEM. EDUC., **15**, 237 (1938).

[3] Ref. 1*e*, pp. 161–2.

TABLE 2

COLLEGES PARTICIPATING AND REPORTING

| Year | Number Participating | Number Reporting | Per cent Reporting |
|---|---|---|---|
| 1935–36 | 105 | 39 | 37.2 |
| 1936–37 | 290 | 162 | 55.9 |
| 1937–38 | 275 | 149 | 54.2 |
| 1938–39 | 287 | 169 | 58.9 |
| 1939–40 | 289 | 180 | 62.3 |
| 1940–41 | 295 | 182 | 61.7 |

these reasons might be added that some teachers may feel that the tests do not measure adequately all their objectives. The committee would welcome suggestions which might serve to make the tests in the future more widely useful.

## THE USES MADE OF THE TEST

This year a study was undertaken to survey the uses to which the test is put. A questionnaire was sent to the teachers who used the test, seventy-seven of whom replied. The replies to the question, "What use did you make of the test?" are given in Table 3.

TABLE 3

USES OF THE COÖPERATIVE CHEMISTRY TEST FOR COLLEGE STUDENTS

| Use of Test | Per cent* of Instructors Replying: Always | Sometimes | Never | No Reply |
|---|---|---|---|---|
| To assign grades to students | 57.1 | 32.5 | 9.1 | 1.3 |
| To compare various classes within your college | 31.2 | 32.5 | 18.2 | 18.2 |
| To advise students about their professional goals | 20.8 | 53.2 | 16.9 | 9.1 |
| To compare your college with national norms | 92.2 | 5.2 | 0.0 | 2.6 |
| To compare teaching ability of instructors within your institution | 0.0 | 16.9 | 46.8 | 36.4 |

* Total $N = 77$.

About half of the teachers suggested other uses, not asked about in the questionnaire. Most of these replies can be grouped in the following categories.

| Number | Suggested Uses |
|---|---|
| 5 | As a placement test (entering students, transfer students) |
| 6 | For diagnostic purposes (guide for emphasis on teaching, allotment of extra recitations, etc.) |
| 4 | To study educational problems (compare textbooks, compare teaching methods, etc.) |
| 11 | To help maintain and improve standards (compare teacher with himself from year to year, stimulate students, etc.) |
| 14 | Miscellaneous replies, such as "selection of student assistants" (3), "to acquaint students (future teachers) with a valuable tool of their profession" (3), etc. |

Thus the first four replies in Table 3 are highly positive, (that is, "always" or "sometimes" responses). It is of some interest to note that the test is rarely used to compare teaching ability.

The replies to the question, "How has this test influenced your classroom teaching?" are given in Table 4.

TABLE 4

INFLUENCE OF THE COÖPERATIVE CHEMISTRY TEST FOR COLLEGE STUDENTS ON CLASSROOM TEACHING

In Terms of the Per Cent of Instructors Stating That the Test Had Influenced Their Teaching in the Given Manner (Total $N = 77$)

How has this test influenced your classroom teaching?

| | |
|---|---|
| (49.3) | Called attention to large individual differences, and consequent need for adapting instruction definitely for students having different abilities, backgrounds, and needs. |
| (74.0) | Indicated specific areas of strength and weakness of students, leading to changes in emphasis in the course. |
| (40.3) | Pointed out differences in effectiveness of various teaching methods tried out, leading to improvement of instruction. |
| (51.9) | Tended to clarify instructor's ideas about objectives of the course, and caused him to place greater emphasis upon essential points. |
| ( 5.2) | Tended to cause instructor to emphasize points tested at the expense of other equally important points. |

There were eleven miscellaneous responses to this question. Practically all these replies fall within the scope of the function of the testing program as indicated by the following quotations: "It has given me a better idea as to the proper passing level"; "It helps me to follow the opinions of great chemistry teachers as to what they consider important"; "more attention to thought questions"; "stimulated students." Here again, a large fraction of the teachers have found that the test has had beneficial influence on their teaching. This is confirmed by the few replies to the last question in Table 4, which is so worded that a check in that reply would be an *adverse* influence.

In order to estimate the role which the test plays in assigning grades relative to other criteria, the teachers were asked to estimate the weight accorded to the various factors. The responses are given in Table 5.

Thus, of all the factors used in assigning grades, the coöperative test ranks second only to teacher-made tests.

An overall appraisal of the replies is that the seventy-seven teachers found the program useful. However, those who replied represent only a small fraction of those who used the test. In order to get a more nearly accurate picture of the usefulness of the program, the coöperation of all those using the test is desired.

TABLE 5

ESTIMATED WEIGHT GIVEN VARIOUS FACTORS IN DETERMINING FINAL GRADES IN ELEMENTARY CHEMISTRY COURSES

Figures Represent Number of Instructors Weighting Each Factor as Indicated (Total $N = 75$)

| | Estimated Weight | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Factor | Not used | 1–10% | 11–20% | 21–30% | 31–40% | 41–50% | 51–60% | 61–70% | 71–80% | Above 80% |
| Coöperative Chemistry Test for College Students | 12 | 11 | 14 | 22 | 10 | 3 | 1 | 1 | 0 | 0 |
| Other published tests | 72 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| Teacher-made tests | 2 | 1 | 8 | 24 | 18 | 12 | 6 | 3 | 1 | 0 |
| Recitations | 28 | 13 | 19 | 9 | 4 | 1 | 0 | 1 | 0 | 0 |
| Homework problems, written reports, etc. | 30 | 23 | 20 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| Laboratory work | 6* | 7 | 22 | 22 | 17 | 1 | 0 | 0 | 0 | 0 |

* Two of these gave separate grades on laboratory work and required that it be "satisfactory" in order to pass course.

### THE STATISTICAL ANALYSIS OF THE 1941 TEST

The 1941 test consisted of four parts: Part I, *Information and Vocabulary;* Part II, *Problems and Equations;* Part III, *Scientific Method;* Part IV, *Qualitative Analysis.* The first three parts taken together are equivalent to the complete test of the past four years. Part IV was added this year as an experiment. The national percentiles are given in Table 6 and are based upon analysis of the hand-scored booklets. Since only about one-half of those reporting took Part IV, it has been necessary to give separate percentiles for the totals of Parts I, II, and III, taken by 7046 students, and for the totals of Parts I, II, III, and IV, taken by 3372 students.

TABLE 6

NATIONAL CHEMISTRY PERCENTILES, FORM 1941

(Booklet Form)

| | *Part I Information and Vocabulary* | *Part II Problems and Equations* | *Part III Scientific Method* | *Total, Parts I, II, and III* | *Part IV Qualitative Analysis* | *Total, Parts I, II, III, and IV* |
|---|---|---|---|---|---|---|
| No. cases | 7046 | 7046 | 7046 | 7046 | 3372 | 3372 |
| No. colleges | 138 | 138 | 138 | 138 | 74 | 74 |
| Mean | 30.1 | 20.1 | 18.4 | 68.7 | 6.7 | 76.1 |
| Maximum score | 81 | 60 | 58 | 199 | 24 | 223 |
| Percentile | | | | | | |
| 99 | 64 | 50 | 41 | 147 | 19 | 165 |
| 98 | 60 | 47 | 38 | 137 | 18 | 155 |
| 97 | 58 | 44 | 37 | 130 | 17 | 146 |
| 96 | 56 | 42 | 35 | 125 | 16 | 141 |
| 95 | 54 | 41 | 34 | 121 | 15 | 136 |
| 94 | 53 | 39 | 33 | 118 | *15* | 131 |
| 93 | 51 | 38 | 32 | 115 | 14 | 129 |
| 92 | 50 | *38** | 31 | 112 | *14* | 126 |
| 91 | 49 | 37 | 30 | 110 | 14 | 124 |
| 90 | 48 | 36 | *30* | 108 | *13* | 122 |
| 88 | 46 | 35 | 29 | 105 | 13 | 117 |
| 86 | 45 | 34 | 28 | 101 | *12* | 112 |
| 84 | 44 | 32 | 27 | 98 | 12 | 109 |
| 82 | 42 | 31 | 26 | 95 | *11* | 106 |
| 80 | 41 | 30 | 25 | 92 | 11 | 103 |
| 75 | 39 | 28 | 24 | 86 | 10 | 96 |
| 70 | 36 | 26 | 22 | 81 | 9 | 90 |
| 65 | 34 | 23 | 21 | 77 | 8 | 85 |
| 60 | 32 | 22 | 20 | 73 | 7 | 80 |
| 55 | 31 | 20 | 19 | 69 | *7* | 76 |
| 50 | 29 | 19 | 18 | 65 | 6 | 72 |
| 45 | 27 | 17 | 17 | 62 | 5 | 68 |
| 40 | 26 | 16 | 15 | 58 | *5* | 65 |
| 35 | 24 | 14 | *15* | 55 | *4* | 60 |
| 30 | 22 | 13 | 13 | 51 | 4 | 56 |
| 25 | 21 | 11 | 12 | 48 | 3 | 52 |
| 20 | 19 | *10* | *11* | 44 | 2 | 48 |
| 18 | 18 | 10 | 11 | 42 | *2* | 46 |
| 16 | 17 | 8 | 10 | 41 | 2 | 44 |
| 14 | 16 | 7 | 9 | 39 | 1 | 42 |
| 12 | 15 | *7* | *9* | 37 | *1* | 40 |
| 10 | 14 | 6 | *8* | 34 | 1 | 37 |
| 9 | 13 | *5* | 8 | 33 | 1 | 36 |
| 8 | 12 | 5 | *7* | 32 | 0 | 35 |
| 7 | *12* | 4 | 7 | 30 | 0 | 34 |
| 6 | *11* | *4* | *6* | 29 | 0 | 33 |
| 5 | 11 | 4 | 6 | 28 | 0 | 30 |
| 4 | 10 | 2 | 5 | 26 | *0* | 28 |
| 3 | 9 | 1 | 4 | 24 | 0 | 26 |
| 2 | 7 | *1* | 3 | 21 | 0 | 24 |
| 1 | 5 | 0 | 2 | 17 | 0 | 20 |

* For repeated entries, enter table with italicized value.

### EQUIVALENT SCORES ON THE MACHINE-SCORED FORM OF THE TEST

In the past three years, an increasing number of students have taken the machine-scored examination. This fact introduces a difficulty in obtaining a single set of national norms, in that the scores made on the two forms are not equivalent. Those who take the machine-scored test are under the added handicap of transferring their answers on a separate answer sheet, and this step introduces opportunities for making slips and reduces the effective examination time.

There is no completely satisfactory solution to this problem. There are, however, two alternative procedures which might give a partial solution. One procedure is to give two separate sets of norms. The objection to this procedure is that the group is thereby broken up into two subgroups, of different scholastic ability, the tendency being for the larger schools to use the machine-scored form. Moreover, it would be difficult to estimate the relative scholastic ability of the two subgroups. Another procedure is to "correct" the scores of those taking the machine-scored form, in order to remove the added difficulty. Martin[4] carried out a study in which he found that, in the group studied, the added difficulty amounted to 13 per cent of the raw scores. He found, moreover, that the difficulty varied for students of different scholastic ability, being greatest near the middle percentile rank. On the basis of this and other similar studies carried out in a large midwestern university, a table of equivalent scores has been prepared. A condensed table of equivalents is given in Table 7, the complete table being obtainable by writing to the Coöperative Test Service.

The fundamental assumptions in this procedure are, first, that the experimental groups which furnished the data for the equivalents are representative, and, second, that every class is handicapped to the same extent. The first assumption is perhaps justified, but it is doubtful that the second one is. The magnitude of the "added difficulty" is primarily a function of the experience of the group in taking machine-scored examinations. In unpublished studies at the University of Chicago, where the students have had wide experience in taking machine-scored tests, the added difficulty is of the order of three to four per cent. The author would recommend, therefore, as a third alternative procedure, the increasing of the raw score by an amount varying from three to ten per cent, depending upon an estimate of the amount of experience of the particular class in taking machine-scored tests. In most cases, however, the results would not differ significantly from those obtained by the Martin procedure.

This problem of equivalence can be completely eliminated in the future by having all students record their answers in separate answer sheets, which could then be scored either by hand or by the machine. This procedure is contemplated for the 1942 test.

[4] MARTIN AND ALLEN, "The 'clerical facility' factor for students taking objectively scored tests by direct answer on the test sheet versus separate answer sheets," J. CHEM. EDUC., **17**, 76–77 (1940).

TABLE 7

ANSWER SHEET—BOOKLET EQUIVALENTS OF RAW SCORES COÖPERATIVE COLLEGE TEST: FORM 1941

| *Part I Information and Vocabulary* | | *Part II Problems and Equations* | | *Part III Scientific Method* | | *Total, Parts I, II, and III* | | *Total, Parts I, II III, and IV* | |
|---|---|---|---|---|---|---|---|---|---|
| *A** | *B*† | *A* | *B* | *A* | *B* | *A* | *B* | *A* | *B* |
| 80 | 80 | 60 | 60 | 58 | 58 | 199 | 199 | 220 | 221 |
| 70 | 73 | 55 | 58 | 55 | 56 | 180 | 183 | 200 | 202 |
| 60 | 63 | 50 | 55 | 50 | 51 | 160 | 164 | 180 | 183 |
| 55 | 60 | 45 | 50 | 45 | 47 | 150 | 157 | 160 | 164 |
| 50 | 56 | 40 | 44 | 40 | 42 | 140 | 151 | 150 | 157 |
| 45 | 48 | 35 | 38 | 30 | 31 | 130 | 144 | 140 | 151 |
| 40 | 42 | 30 | 32 | 20 | 21 | 120 | 135 | 130 | 144 |
| 30 | 32 | 20 | 21 | 10 | 11 | 110 | 120 | 120 | 135 |
| 20 | 23 | 10 | 12 | | | 100 | 105 | 110 | 120 |
| 10 | 15 | | | | | 80 | 83 | 100 | 105 |
| | | | | | | 60 | 66 | 80 | 83 |
| | | | | | | 40 | 47 | 60 | 65 |
| | | | | | | 20 | 27 | 40 | 47 |
| | | | | | | 10 | 15 | 20 | 27 |
| | | | | | | | | 10 | 15 |

* Answer sheet raw score.
† Booklet raw score.

TABLE 8

CONDENSED PERCENTILE CORRESPONDING TO TOTAL RAW SCORES FOR VARIOUS SPECIAL GROUPS

| | *Sex Difference* | | *Effect of High-School Chemistry* | | *Type of College* | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *All Men* | *All Women* | *High-School Chemistry* | *No High-School Chemistry* | *Men's Liberal Arts* | *Women's Liberal Arts* | *Coeducational Liberal Arts* | *Teachers College* | *Agricultural and Technical College* | *Engineering College* | *Junior College* | |
| Mean | 73.2 | 58.9 | 74.3 | 56.0 | 71.0 | 60.4 | 71.1 | 58.5 | 62.3 | 71.9 | 68.4 | |
| No. cases | 4809 | 2237 | 4914 | 2070 | 1222 | 885 | 3246 | 352 | 104 | 321 | 825 | |
| Percentile | | | | | | | | | | | | Percentile |
| 99 | 151 | 127 | 150 | 128 | 148 | 122 | 148 | 132 | 147 | 148 | 149 | 99 |
| 98 | 142 | 118 | 142 | 116 | 141 | 114 | 138 | 122 | 145 | 136 | 145 | 98 |
| 93 | 120 | 100 | 120 | 96 | 117 | 101 | 118 | 107 | 106 | 119 | 118 | 93 |
| 90 | 113 | 94 | 113 | 88 | 109 | 96 | 111 | 97 | 99 | 110 | 111 | 90 |
| 84 | 103 | 85 | 104 | 80 | 98 | 85 | 101 | 89 | 91 | 100 | 100 | 84 |
| 80 | 97 | 81 | 98 | 76 | 93 | 82 | 95 | 82 | 86 | 94 | 92 | 80 |
| 75 | 91 | 75 | 92 | 71 | 88 | 76 | 89 | 74 | 79 | 88 | 86 | 75 |
| 70 | 86 | 70 | 87 | 67 | 83 | 71 | 84 | 69 | 75 | 81 | 81 | 70 |
| 60 | 77 | 63 | 78 | 59 | 75 | 64 | 75 | 61 | 66 | 75 | 74 | 60 |
| 50 | 70 | 56 | 71 | 53 | 67 | 58 | 68 | 54 | 55 | 68 | 65 | 50 |
| 40 | 63 | 49 | 64 | 47 | 60 | 52 | 61 | 47 | 50 | 61 | 56 | 40 |
| 30 | 56 | 44 | 57 | 41 | 54 | 45 | 54 | 42 | 43 | 56 | 49 | 30 |
| 25 | 52 | 40 | 54 | 38 | 50 | 42 | 50 | 39 | 39 | 51 | 46 | 25 |
| 20 | 48 | 37 | 49 | 34 | 47 | 39 | 46 | 34 | 36 | 48 | 43 | 20 |
| 16 | 45 | 34 | 46 | 32 | 44 | 35 | 43 | 30 | 34 | 45 | 38 | 16 |
| 10 | 38 | 28 | 40 | 27 | 37 | 31 | 36 | 24 | 29 | 41 | 32 | 10 |
| 7 | 34 | 26 | 36 | 24 | 34 | 28 | 32 | 21 | 26 | 38 | 29 | 7 |
| 2 | 25 | 17 | 26 | 16 | 25 | 19 | 22 | 15 | 17 | 29 | 20 | 2 |
| 1 | 21 | 14 | 21 | 13 | 20 | 17 | 17 | 13 | 15 | 27 | 16 | 1 |

## THE FACTORS OF SEX DIFFERENCE, PREVIOUS TRAINING, AND TYPE OF COLLEGE ATTENDED

Table 8 shows the effects of the factors of sex difference, previous training, and type of college attended. These factors have been studied repeatedly, and the results do not differ significantly from those found in the past. They are given here as a record for future studies.

## VARIABILITY BETWEEN COLLEGES

The factor of variability between colleges has likewise been studied repeatedly. The results of this year's analysis are given in Table 9. The mean scores of the colleges vary from the third to the ninety-seventh percentile, although half of them fall between the thirty-sixth and sixty-fifth percentile. This high variability among the colleges signifies that the colleges are inherently different in so far as performance in chemistry is concerned.

TABLE 9

DISTRIBUTION OF THE MEAN SCORES OF 197 COLLEGES ON THE COÖPERATIVE CHEMISTRY TEST, FORM 1941 (PARTS I, II, AND III)

| National Percentile Total Parts I, II, III | 0–5 | 6–15 | 16–25 | 26–35 | 36–45 | 46–55 |
|---|---|---|---|---|---|---|
| No. of colleges | 1 | 5 | 19 | 19 | 37 | 30 |

| National Percentile Total Parts I, II, III | 56–65 | 66–75 | 76–85 | 86–95 | 96–100 |
|---|---|---|---|---|---|
| No. of colleges | 30 | 29 | 18 | 7 | 1 |

## THE FACTOR OF PROFESSIONAL GOALS

Table 10 shows the relation between professional goals and performance on the test. This year the categories "chemist" and "chemical engineer" were added. It is perhaps not surprising that these two groups show the highest performance, of practically the same magnitude. As a result of these two new categories, "college teaching," which in past studies was the highest, has dropped to third place, while "engineering (other than chemical)" is now a little higher than the average. "Home economist" continues to show the lowest performance.

TABLE 10

PERCENTILE EQUIVALENTS FOR RAW SCORES ON THE COÖPERATIVE CHEMISTRY TEST FOR COLLEGE STUDENTS, FORM 1941, FOR STUDENTS IN BEGINNING CHEMISTRY COURSES CLASSIFIED ACCORDING TO PROFESSIONAL GOAL

| *Professional Goal* | *Total Number* | *Part I* | *Part II* | *Part III* | *Total I, II, and III* |
|---|---|---|---|---|---|
| Chemist | 440 | 80 | 75 | 80 | 82 |
| Chemical Engineer | 284 | 80 | 75 | 82 | 82 |
| Engineer (other than chemical) | 1051 | 55 | 60 | 60 | 60 |
| College Teacher | 87 | 73 | 65 | 73 | 73 |
| Secondary-School Teacher | 276 | 60 | 58 | 50 | 57 |
| Farmer | 55 | 45 | 48 | 40 | 46 |
| Businessman | 220 | 48 | 50 | 50 | 50 |
| Physician | 919 | 60 | 58 | 55 | 59 |
| Science Major | 308 | 60 | 55 | 55 | 59 |
| Home Economist | 450 | 33 | 35 | 30 | 29 |

## THE PROBLEM OF PASSING GRADES

This year the instructors were asked to indicate what they consider a passing grade for their class, on the coöperative test. It is unfortunate that only 77 have returned the questionnaire, and that, of those, only 71 replied to this question. In addition, the group was divided into a subgroup of 34, who did not use Part IV (qualitative analysis), and a subgroup of 27, who did use Part IV. Although these numbers are too small to give statistically reliable results, they are suggestive of a trend. The relation of passing grade to the mean of a class is given in Tables 11 and 12. The coefficient of correlation between class mean and passing grade is 0.60 for those who did not use qualitative analysis and 0.59 for those who did.

TABLE 11

RELATION OF PASSING GRADE TO AVERAGE SCORE FOR 34 SCHOOLS WHICH ADMINISTERED ONLY PARTS I, II, AND III

| *Passing Grade* | *Class Average* 40–49 | 50–59 | 60–69 | 70–79 | 80–89 | 90–99 | 100–109 |
|---|---|---|---|---|---|---|---|
| 60–69 | .. | 1 | 1 | 3 | .. | .. | 1 |
| 50–59 | .. | .. | 2 | 1 | 2 | 1 | .. |
| 40–49 | .. | 1 | 2* | 2 | .. | .. | .. |
| 30–39 | 3 | 1 | 2 | 3 | .. | .. | .. |
| 20–29 | 1 | .. | .. | .. | .. | .. | .. |

* Average passing grade 44.5; national class average 68.7.

TABLE 12

RELATION OF PASSING GRADE TO AVERAGE SCORE FOR 27 SCHOOLS WHICH ADMINISTERED PARTS I, II, III, AND IV

| *Passing Grade* | *Class Average* 60–69 | 70–79 | 80–89 | 90–99 | 100–109 | 110–119 |
|---|---|---|---|---|---|---|
| 80–89 | .. | .. | 1 | .. | .. | 1 |
| 70–79 | .. | .. | .. | 2 | .. | .. |
| 60–69 | 1 | * | .. | 2 | .. | .. |
| 50–59 | 2 | 2 | 1 | 1 | .. | .. |
| 40–49 | .. | 1 | 3 | .. | .. | .. |
| 30–39 | 1 | 3 | .. | .. | .. | .. |

* Average passing grade 53.5; national class average 76.1.

## RELATION OF PERFORMANCE TO TIME DEVOTED TO LECTURE HOURS, LABORATORY HOURS, AND CREDIT HOURS

Table 13 gives the performance in Parts I, II, III, and total for various combinations of lecture hours, laboratory hours, and credit hours.

All attempts to analyze the data for relations between performance and any of the three variables (lecture hours, laboratory hours, and credit hours) lead to the conclusion that the variability among the classes that reported is so great as to overshadow the effect of these variables. Table 14, which is derived from Table 13, gives the relation of performance to credit hours. The results show that the mean score is about 70, irrespective of the number of credit hours.

TABLE 13

MEAN SCORES ON THE COÖPERATIVE CHEMISTRY TEST FOR COLLEGE STUDENTS, FORM 1941, FOR STUDENTS WITH VARYING COMBINATIONS OF LABORATORY HOURS, LECTURE HOURS, AND CREDIT HOURS IN THE BEGINNING CHEMISTRY COURSE

| *Lecture Hours* | *Lab. Hours* | *Credit Hours* | *N* | *Part I* | *Part II* | *Part III* | *Total Parts I, II, and III* |
|---|---|---|---|---|---|---|---|
| 2 | 2 | 3 | 12 | 29.8 | 22.3 | 20.1 | 72.3 |
| 2 | 2 | 4 | 33 | 30.1 | 19.6 | 15.4 | 65.2 |
| 2 | 3 | 3 | 9 | 21.7 | 13.1 | 9.6 | 44.3 |
| 2 | 3 | 4 | 197 | 30.5 | 20.8 | 17.9 | 69.1 |
| 2 | 4 | 3 | 51 | 33.0 | 27.0 | 23.0 | 83.0 |
| 2 | 4 | 4 | 984 | 27.3 | 17.5 | 17.1 | 61.9 |
| 2 | 5 | 4 | 34 | 23.0 | 12.0 | 16.7 | 51.7 |
| 2 | 6 | 4 | 284 | 28.2 | 18.3 | 17.8 | 64.4 |
| 3 | 1 | 4 | 158 | 34.2 | 20.2 | 19.4 | 73.9 |
| 3 | 2 | 3 | 182 | 25.5 | 17.0 | 16.7 | 59.2 |
| 3 | 2 | 4 | 359 | 26.8 | 18.6 | 16.3 | 61.7 |
| 3 | 2 | 5 | 61 | 34.3 | 25.7 | 22.3 | 82.2 |
| 3 | 3 | 3 | 160 | 32.7 | 22.5 | 19.6 | 74.8 |
| 3 | 3 | 4 | 1744 | 30.7 | 20.9 | 19.3 | 70.9 |
| 3 | 3 | 6 | 172 | 33.2 | 21.0 | 16.4 | 70.6 |
| 3 | 4 | 3 | 130 | 37.0 | 27.4 | 23.4 | 87.8 |
| 3 | 4 | 4 | 971 | 28.8 | 18.6 | 16.6 | 64.0 |
| 3 | 4 | 5 | 238 | 29.2 | 18.8 | 15.9 | 64.0 |
| 3 | 5 | 4 | 82 | 28.6 | 20.1 | 17.8 | 66.5 |
| 3 | 5 | 5 | 70 | 39.7 | 26.2 | 25.0 | 90.9 |
| 3 | 6 | 4 | 106 | 34.2 | 25.8 | 19.2 | 79.2 |
| 3 | 6 | 5 | 683 | 34.5 | 22.9 | 21.1 | 78.6 |
| 3 | 6 | 6 | 12 | 37.2 | 25.3 | 23.9 | 86.5 |
| 4 | 0 | 4 | 24 | 20.5 | 11.0 | 13.2 | 44.7 |
| 4 | 3 | 5 | 192 | 28.0 | 18.1 | 19.0 | 65.2 |
| 4 | 4 | 4 | 47 | 31.6 | 27.0 | 23.4 | 82.0 |
| 4 | 6 | 5 | 12 | 40.1 | 32.6 | 25.0 | 97.7 |

TABLE 14

RAW SCORE ON PARTS I, II, AND III OF THE COÖPERATIVE CHEMISTRY TEST, FORM 1941, VS. CREDIT HOURS

| *Credit Hours* | *Raw Score* | *N* |
|---|---|---|
| 3 | 72.9 | 544 |
| 4 | 66.7 | 5023 |
| 5 | 74.9 | 1256 |
| 6 | 71.6 | 184 |

Table 15, also derived from Table 13, shows the performance for various combinations of lecture hours and laboratory hours. In this table, the differences in credit hours were ignored, since it was shown in Table 14 that they had no appreciable influence. Thus, while some trends are discernible, the results of this study could not be used to estimate even roughly the effect of lecture hours or laboratory hours on performance. In order to estimate the effect of these factors, the other

TABLE 15

RAW SCORE FOR VARIOUS COMBINATIONS OF LECTURE HOURS AND LABORATORY HOURS

| *Laboratory Hours* | *Lecture Hours* 2 | 3 | 4 | *Mean Score* | *Total Number* |
|---|---|---|---|---|---|
| 0 | .... | .... | 44.7 | 44.7 | 24 |
| 1 | .... | 73.9 | .... | 73.9 | 158 |
| 2 | 67.1 | 63.0 | .... | 63.3 | 647 |
| 3 | 68.0 | 71.3 | 65.2 | 70.4 | 2474 |
| 4 | 62.9 | 66.3 | 82.0 | 65.2 | 2421 |
| 5 | 51.7 | 77.7 | .... | 73.0 | 186 |
| 6 | 64.4 | 78.8 | 97.7 | 75.3 | 1097 |
| Mean score: | 63.7 | 70.4 | 67.7 | | |
| Total number: | 1604 | 5128 | 275 | | |

factors, such as type of college, proportion of men to women, etc., should be kept constant.

### THE DIFFICULTY OF THE COÖPERATIVE CHEMISTRY TEST

The difficulty of a test may be measured by the ratio of the mean score to the maximum obtainable score. The difficulty of the coöperative test for the past four years is given in Table 16.

TABLE 16

DIFFICULTY OF TESTS: RATIO OF MEAN SCORE TO MAXIMUM OBTAINABLE SCORE, FOR EACH PART AND TOTALS FOR THE COÖPERATIVE CHEMISTRY TESTS OF 1938, 1939, 1940, AND 1941

| | *Part I* | *Part II* | *Part III* | *Total Parts I, II, and III* | *Part IV* | *Total Parts I, II, III, and IV* |
|---|---|---|---|---|---|---|
| 1938 | 42.7* | 24.6 | 27.5 | 32.7 | | |
| 1939 | 43.9 | 32.3 | 33.2 | 37.1 | | |
| 1940 | 41.9 | 32.9 | 26.5 | 34.1 | | |
| 1941 | 37.2 | 33.5 | 31.7 | 34.5 | 27.9 | 34.1 |

Under normal circumstances, it is desirable that the difficulty is of the order of 50 per cent, so that the test would have a maximum discriminating power for good as well as poor students. The author has been somewhat concerned by the fact that the coöperative tests have been too difficult. Of course, it is desirable that the test be difficult enough so that no student obtains a perfect score, but this is not the only criterion. An examination of the tests reveals that from one-fourth to one-third of each test is used merely to distinguish between the 98th and 100th percentile. Thus, in the 1941 test the 98th percentile corresponds to a raw score of 137 out of a maximum of 199.

It might be pointed out that the test can be difficult if it contains the following types of items:

(*a*) Items which require a high scholastic ability, high intelligence, good training, etc.;
(*b*) Items which, though simple in themselves, are not generally known, so that only a small fraction of the population are acquainted with them;
(*c*) Items which are ambiguous or have no clear-cut answers.

Items of type *c* can be eliminated by careful consideration on the part of those constructing and editing the test. It is believed that there are few, if any, of this type in the coöperative test. Items of type *a* are legitimate and should be included in the test, but care should be taken to prevent their being heavily represented. Items of type *b* present a problem. If the courses vary widely it becomes a task to find relatively easy items which are widely taught.

There are two methods which can be used in overcoming this difficulty. One is to survey as widely as possible the judgment of instructors on the appropriateness of the item. The other is to analyze the items statistically for discriminating power. For, if the items are difficult only because few people happen to be acquainted with them, then good students are almost as likely to miss them as poor students. Such an item analysis of the 1941 test is contemplated, with the view that the results will be used as a guide in the selection of items in future tests.

### THE 1942 COÖPERATIVE TESTS

The accumulation of data and experience of the past six years has had the effect of modifying the concept of what a test should measure. As a result of extensive discussion in the conference of June 21 to 27, referred to above, the 1942 test is considerably different from the tests of the past four years. The following is a brief description of the test.

Part I. General Knowledge and Information.
This part attempts to measure knowledge or *acquaintance with* important facts, definitions, laws, and theories of chemistry. Historical events, and applications of chemistry to the social and economic world, are represented.

Part II. Application of Principles.
This part attempts to measure the ability to solve numerical problems, balance equations, and make qualitative predictions by the application of chemical principles.

Part III. Scientific Method.
This section attempts to measure the understanding of the relation of observations, definitions, laws, and theories in the scientific procedure. The relation of theory to experiment is represented, as well as the ability to interpret chemical data.

Part IV. Knowledge of Laboratory Technic and Procedure.
This section attempts to measure acquaintance with the laboratory and knowledge of "correct" procedures. It does not attempt to measure skill or technic as such.

The teachers who constructed this test are aware that the test will fall short of the ideal. The test can be improved only by the constant criticism of all those who use it.

The committee wishes to thank each department and each teacher who collaborated in the program. It also wishes to thank Miss Ruth A. Pedersen, and the other members of the Coöperative Test Service for making the numerous statistical studies for this report.

The Committee on Examinations and Tests, Division of Chemical Education:

B. CLIFFORD HENDRICKS — ED. F. DEGERING
RUFUS D. REED — LAURENCE S. FOSTER
EARL W. PHELAN — THEODORE A. ASHFORD
O. M. SMITH, *Chairman*

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***"In the years of toil and struggle ahead, our former negligence in the preparation of young people for the present situation is likely to rise up to haunt us. For the future we must redouble our efforts to prepare oncoming youth adequately for the burdens and responsibilities both of war and peace."***

**—From *Youth and the Future***

# Modern Abrasives

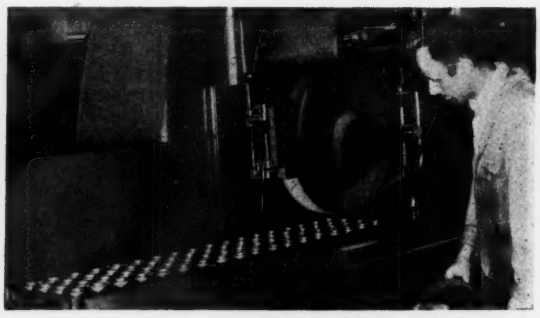
HERMON C. COOPER *Norton Company, Worcester, Massachusetts*

***Modern abrasives have gone to war, as shown in the page of special illustrations, with which this up-to-date general article is prefaced.***

*Courtesy of Curtiss-Wright Corporation*

FIGURE 1

The hollow chromium-vanadium steel *airplane propeller blades* are being rounded on the edges to exact contour (see gage plate) with a portable motor driving a flexible disc on which abrasive is spread. Note identification badge.



*Courtesy of Mattison Machine Works*

FIGURE 2

*A typical case of mass production* is shown by this flat magnetic chuck full of steel caps (parts for machine tools) traveling back and forth underneath an abrasive wheel. Seventy-five pieces are ground with precision in 30 minutes instead of 7 hours, as formerly

*Courtesy of Baldwin Locomotive Works, Standard Steel Works Division*

FIGURE 3

*Anti-aircraft gun mount base* being ground smooth with a resin-bonded, fused alumina wheel, hitting the rough places at a speed of 140 feet per second. The wheel support is free to move in any direction.

FIGURE 4

Not all grinding wheels are large. This *small one*, perhaps of rubber-bonded alumina, is perfecting the steel form (die) into which an aluminum billet is to be jammed by a trip hammer to make an engine crankcase forging.

*Courtesy of Erie Foundry and Aluminum Company of America*

FIGURE 6

Not shoes but *magnesium alloy castings for Cyclone engines* are being ground on the side of the Bakelite-bonded (Gardner) disc grinder. Production is rapid. Gloves save skin abrasions.

*Courtesy of Wright Aeronautical*

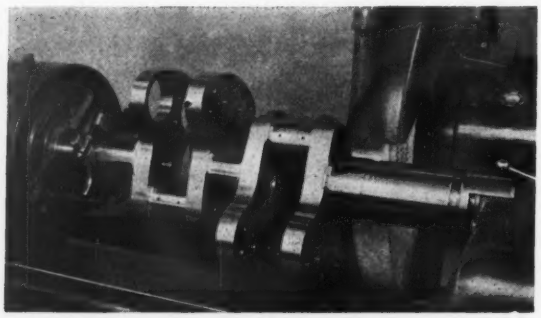


FIGURE 5

*Crankshaft of a Pratt and Whitney 2800 aeronautical engine* all set to be ground to precision with a vitrified wheel of fused alumina.

## INTRODUCTION

IT IS the purpose of this article to show how chemistry has revolutionized the abrasive industry and controls it, how the use of abrasives has expanded, and why the sale of abrasive products in the United States alone and before our entrance into the war was approaching $100,000,000 a year.

## SYNTHETIC ABRASIVES, THEIR INVENTION AND MANUFACTURE

Few chemical industries have more of the thrilling fascination of invention, sometimes called romance, than the abrasive industry. The modern brain-children of this industry were cradled in the electrical furnace.

### *Silicon Carbide*

At about the time young Hall found out how to make aluminum metal electrochemically, Edward Acheson (1891) was attempting to harden clay—and maybe make diamonds—by heating the clay together with carbon in a homemade electric arc furnace. After the experiment he observed a few bright grains at the end of the carbon electrode. They were found to be hard enough to cut glass and were the beginning of a new industry. Acheson called his product "carborundum." It proved to be synthetic silicon carbide, SiC, produced by the reaction

$$SiO_2 + 3C \rightarrow SiC + 2CO$$

This discovery probably did more than any other to command respect abroad for American chemical invention and at the same time furnished the starting point for the extensive industrial development at Niagara Falls.

In an early form of his furnace, illustrated diagrammatically in Figure 7 and after which the industrial furnaces of today are modeled, a box of bricks was set up, the carbon electrodes were run in through the ends, and the interior was filled with the charge, except along the line between the electrodes, where a

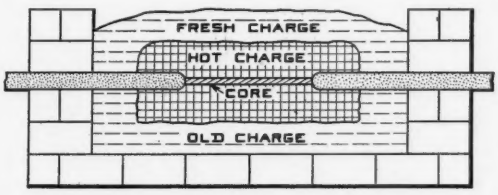



FIGURE 7.—ACHESON'S BRICK FURNACE FOR MAKING CARBORUNDUM

core of carbon was laid beforehand for starting the current. As soon as the charge was heated, it became a fair conductor and he had a core-resistance type of furnace.

Figure 8 shows a commercial furnace of today. Note the concrete end supporting the thick, round, carbon electrode *E*, and the electrical connections. A tubular collar, *C*, around the electrode carries cold water for keeping the electrical connections, *T*, from melting. The charge is crushed to one-fourth-inch

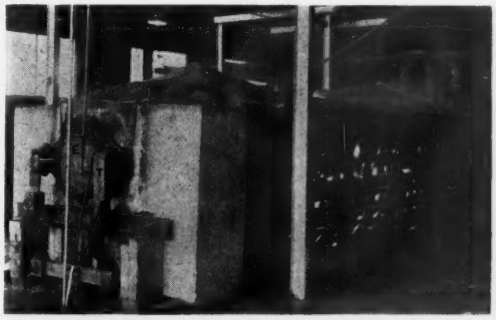


FIGURE 8.—ELECTRIC FURNACE FOR MANUFACTURING SILICON CARBIDE

pieces and filled in from above. The sectional iron framework that supports the charge is a series of gates that can be let down to rake out the charge on cooling. The crust on top of the charge in the picture has been broken through by blowholes of burning gas. The haze overhead is smoke. At the core the temperature is 2200°C.; on the outside of the "gates" jets of carbon monoxide are constantly catching fire; but two inches inside the "gates" the charge is scarcely warm. The outer unreacted part is used over in the next run. The product itself is uncommonly beautiful with its lustrous black plates and columns that develop an iridescent effect by oxidation. Silicon carbide is known under the trade names of Carborundum, Crystolon, Carbolon, Carbonite, Electrolon, etc. It is one of the chief abrasives of the industry, used in general when a very hard material is required.

### *Fused Alumina*

The most extensively used abrasive is fused aluminum oxide, or synthetic corundum, $Al_2O_3$, originally called "alundum," also the invention of an American, Charles B. Jacobs, and also an electric furnace product. Approximately 75 per cent of all the grinding wheels produced are made of it because of its toughness. Figure 9 shows the Higgins alundum furnace for fusing alumina in a combined side view and vertical section. It consists of a sheet iron casing *AA* resting on a base *B* protected by carbon blocks *C*. A pair of carbon electrodes, *EE*, can be lowered into the furnace. When the batch, consisting of bauxite, $Al_2O_3 + xH_2O$ (preheated to drive off the water), together with coke and iron borings, is shoveled in, the electrodes are connected by loose coke laid from one to the other, causing the heat to start. As soon as a layer of molten alumina *L* forms, it carries the current. More charge *R* is added and the electrodes are raised, whereupon an arc is formed (through the non-conducting fresh charge) from each electrode to the melt (note arrows), so we

have an arc type furnace, giving a temperature above 2000°C. Water is kept flowing over the iron casing, so that the molten alumina solidifies to crystalline

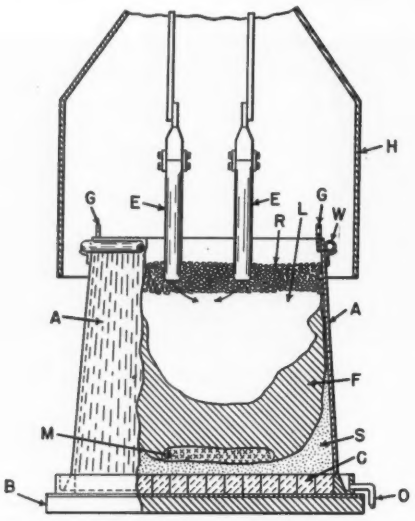



FIGURE 9.—HIGGINS FURNACE FOR FUSING ALUMINA

*AA*—Iron casing; *B*—Base; *C*—Carbon blocks; *EE*—Electrodes; *F*—"Fused" alumina, resolidified; *GG*—Rings for hoist; *H*—Hood; *L*—Molten alumina; *M*—Metal layer (ferrosilicon); *O*—Water drain-off; *R*—Raw charge; *S*—Sintered charge; *W*—Perforated coil of pipe for water supply

alumina *F* and forms a refractory lining, or, we might say, its own crucible. At the end of the run the casing is lifted off by hooking a hoist into the rings *GG* and the solid mass, on cooling, is broken up and processed. Specimens of great beauty can be collected, resembling the natural corundum, but to the operating scientists the beauty that is the real badge of success is that of the finished steel or other product upon which the abrasive is used. Various trade names for fused aluminum oxide are Alundum, Aloxite, Borolon, Exolon, Lionite, and Radiolite.

### *Boron Carbide*

A still harder abrasive substance is boron carbide, $B_4C$, another electric furnace product, termed "norbide" by the discoverer, R. R. Ridgway. It is the hardest substance ever made commercially by man, ranking next to diamond. It is made by causing boric oxide ($B_2O_3$) to react with coke (C), in a special carbon resistance furnace at about 2800°C., producing 99 per cent pure boron carbide ($B_4C$). It is molded in a similar furnace, no bonding substance being necessary.

## AVAILABLE ABRASIVE MATERIALS

Thus with the help of the electric furnace supplementing the gifts of nature, we have a score or so of abrasive materials from which to choose. Those in the first column of the accompanying table are listed in the order of their hardness. Those in the second column constitute a miscellaneous collection of materials that have been found valuable—some from aboriginal days—for various purposes, a number of which will occur to the reader. Sometimes the grains are used as such; sometimes they are spread out on tough paper and stuck to it with glue, giving us sandpaper; sometimes they are molded into a compact wheel, known as an abrasive, or grinding, wheel; or the grains may be pulverized still finer and used as a polishing powder, perhaps in scouring-soap or in perfecting lenses for spectacles or telescopes. Naturally the chiseling action of the grains must be on so fine a scale in finishing lenses that the eye cannot detect the scratches.

TABLE OF ABRASIVE MATERIALS

| | |
|---|---|
| Diamond | Feldspar mineral |
| Boron carbide | Iron and steel, grit, shot, and wool |
| Silicon carbide | Pumice, a keen volcanic product |
| Fused alumina | Diatomaceous earth, a siliceous deposit in the shells of diatoms |
| Garnet crystals | Tripoli, a siliceous earth |
| Quartz crystals, including sand | Quicklime |
| | Rouge and crocus, made by heating ferrous sulfate until it forms ferric oxide |

The variety of abrasive tools demanded is due to the various types of work to be done. We shall consider only grinding wheels.

## MANUFACTURE OF ABRASIVE WHEELS

In making grinding wheels, there are three important factors: the grains, the bond, and the density or porosity. The processing and selection of the grains are important, as is also the density control of the wheels, but the industrial chemist is more concerned with the bond. The common bonds are: (1) vitrified, or ceramic; (2) silicate; (3) shellac; (4) hard rubber; (5) resinoid, or plastic.

*Vitrified Bond.*—This is the most common bond. It softens under heat and becomes like glass, whence the name "vitrified." A batch of clay, feldspar, and other ceramic materials is mixed up in the same way as for ceramic objects, the abrasive grains are incorporated, and the whole is molded into shape and baked in a kiln at 1275°C. About three-fourths of all the wheels at present manufactured are made by the vitrified process. A main essential is to make a bond with nearly the same coefficient of heat expansion as the grit. The vitrified bond is somewhat brittle, so that it is generally limited to a speed of 6500 surface feet per minute or less, but it is used in a great deal of heavy work. It is not affected by water, mild acids, oils, and ordinary weather conditions.

*Silicate Bond.*—Here the abrasive is mixed with silicate of soda, or water glass, and then pressed into the mold, dried, and baked at 250°C. for one to three days. This silicate bond does not hold the grains as tightly as the vitrified bond, hence it makes a softer wheel which is used for developing the edge on tools.

*Shellac Bond.*—It seems strange to go to India for a

binding material to use in making abrasive wheels in the United States, but industrial chemistry knows no geography, provided the raw material can be brought to the chemical factory's receiving room. Shellac is produced by insects, which extract the sap of trees and deposit a liquid that forms a casing on the twigs. This can be tapped off and collected. After it has been cleaned it is mixed with the grit in a steam-heated machine. The wheels are molded in a hydraulic press that heats the mold at the same time. Then they are baked for a few hours at about 150°C. It is used mostly with fine grit for finishing jobs, such as putting high finishes on cam shafts and on rolls in mills. It is also used for giving an edge to knives and sharpening the teeth of saws in lumber mills. It is probable that shellac will gradually be replaced by the synthetic resins, since shellac is a single natural product subject to variation, while the synthetic resins are to be had in great variety and run more uniform.

*Rubber Bond.*—Bonding with rubber is very similar to the making of hard or vulcanized rubber, the grit being incorporated with the soft rubber and vulcanizing agent (sulfur) and the whole being put through the mixing rolls and calender rolls. The wheels are cut out like cookies and baked in confining molds.

Rubber wheels are important in high-speed grinding; they are especially good for cutting off, or sawing. The thinnest abrasive wheels made are made of rubber. Those used to split the points of pens are as thin as a sheet of paper. To get an idea of the thickness, the reader might try working the corner of a sheet of writing paper into the hole of a fountain pen point and then pointward through the slit.

*Resinoid Bond.*—This is the term given to any synthetic resin used as a bond. The number of synthetic resins must already be above a thousand, there being about three thousand trade names. All the promising resins have been tried in grinding wheels, but only two types are in common use: (1) the phenol-formaldehyde type, represented by Bakelite; (2) the alkyd type, represented by the Glyptal resins. The former is a reaction product of phenol and formaldehyde; the latter results from combining glycerin and phthalic acid. Nearly all the first products of these resinoid reactions have a strong tendency to further reaction, either with themselves or with one or both of the original substances, leading rapidly to enormous molecules of very complex structure, which are characteristic of resins. We give a little more attention to resinoid bonds, since they constitute a newer field for research in the grinding-wheel industry. Some resins soften on heating and return to their original condition on cooling; others set on heating and harden. These are the more suitable for grinding wheels. Various substances are combined with the resins: (1) the *catalysts*, such as hexamethylene tetramine to control the setting time of the phenol formaldehyde; (2) the *plasticizer, e. g.*, furfural, which softens (gelatinizes) the uncured resin and makes it adhere more readily to the grit; and (3) the *filler*, such as ground quartz, which improves the cutting action. In manufacturing resinoid wheels one has to be guided by the peculiarities of the resin but, in general, the grit is first thoroughly moistened with the plasticizer; then a mixture of powdered resin and filler is added. The whole is spread in a mold and compressed to size, cold, by hydraulic pressure. Then the "green" wheel, already fairly firm, is set on a flat inert ceramic disc in an oven and given a bake which provides sufficiently slow temperature rise to allow the water liberated from the condensation reaction to escape harmlessly. It continues for a day or two at the temperature, say 160°C., that gives the best results (strongest wheels).

Resinoid wheels are capable of high speed (9500 surface feet per minute) and stand hard use. Shellac, rubber, and resinoid wheels are more elastic than the others. In order to appreciate the value of modern abrasive tools one needs to see and hear a wheel 16 inches in diameter and $2^1/_2$ inches thick rasping at a large casting of steel at high speed, hurling away a stream of white-hot metal particles as it clears off the numerous surface imperfections (Figure 3); or watch a wheel 16 inches in diameter and only $^1/_8$ inch thick tear through a thick steel rod like a buzz saw through wood, and at the same speed.

### HOW THE ABRASIVE WHEEL FUNCTIONS

The action of an abrasive wheel is a tremendous multiplication of the chiseling of a single grain. It has been calculated that for a 46-mesh grain wheel 18 inches in diameter and 2 inches thick and traveling at 5000 surface feet per minute, approximately 38,800,000 cutting points will act per minute.

The abrasive grains in a working wheel do not wear down slowly; they keep breaking off and presenting fresh points. A single coarse grain in a hard wheel may undergo as many as twenty-five fractures. The bond does not do any abrading; it just holds the abrasive grains in position until they are worn down. The pieces of grain that are broken off are swept out, together with the particles of the object ground, by the

FIGURE 10.—ASSORTED GRINDING WHEELS

speedily rotating wheel. If the bond does not follow suit but clogs the wheel surface, the surface will have to be cleaned with a dressing tool. One can thus understand why the following three qualities are important

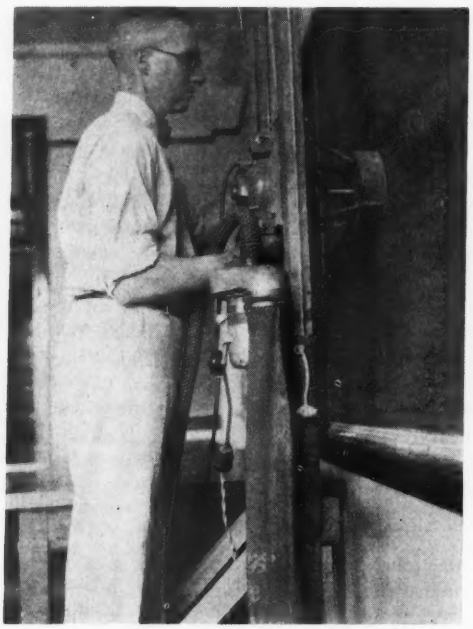


FIGURE 11.—RESURFACING A BLACKBOARD

in an abrasive wheel: (1) hardness, the specific scratching power; (2) toughness, or strength; and (3) nature of fracture.

Silicon carbide wheels are used for grinding soft, ductile metals, like aluminum and copper, and hard, brittle materials, like stone, cast iron, and cemented carbides. Aluminum oxide wheels are better on strong, tough steels, which accounts for their more extensive use.

The manufacturer's markings on the wheels give the characteristics and make it possible to choose a wheel adapted to the work in hand.

What surprises an ordinary individual is the great variety of shapes and sizes of grinding wheels and tools, approaching fifty thousand in number. This is evidence of their wide applicability (Figure 10). What surprises the abrasive manufacturer or researcher in abrasives is the endless array of special customer problems and the discriminating demands of the trade. Thus, in order to make the manufacture of low-priced pocket knives a paying enterprise, an abrasive wheel must be supplied that will grind the blades to a sharp edge and give a high finish and rapid output without destroying the temper of the blade. Ability to do this demands the right kind and size of grit, sufficient toughness of the bond, and the elimination of abraded material from the surface of the blade.

### INTERESTING USES OF ABRASIVE WHEELS

We are ready now to look at some of the applications of grinding wheels:

(1) Coarse grinding or "snagging," including the removal of imperfections and elevations from the surfaces of castings and welding jobs (Figure 3). Wheels for this work are made of coarser grains and frequently are resinoid bonded.

(2) Precision grinding to size and shape. The mount resembles a large lathe (Figure 2). The wheels are generally smaller and made of finer grains.

(3) Grinding surfaces. We are familiar with machines for resurfacing floors, in which sandpaper is fastened on a rotating cylinder instead of using a grinding wheel. The same principle can be used not only for the grinding of metal surfaces but even for resurfacing blackboards, as is shown in Figure 11, where a simple framework has been built to guide the grinding wheel. One can readily understand how grinding wheels can be adapted to any grinding task by making a suitable device to hold and move the wheel against the object to be ground. Often it is better to hold the wheel firm and move the object back and forth and sidewise on a shelf underneath the wheel. If one has a general purpose grinding wheel, he can sharpen skates, *i. e.*, put a fresh surface on the runners, as shown in Figure 12. Since the skate moves in a single line, it can be seen that it will be ground slightly "hollow" which is to be desired.

(4) Cutting metals. The abrasive cut-off wheel is thin; $^{3}/_{32}$ inch is a typical thickness. It is mounted like a circular saw and runs at high speeds, such as 5000 revolutions per minute for a wheel 12 inches in diameter. This wheel replaces metal cutting-off tools to some extent.

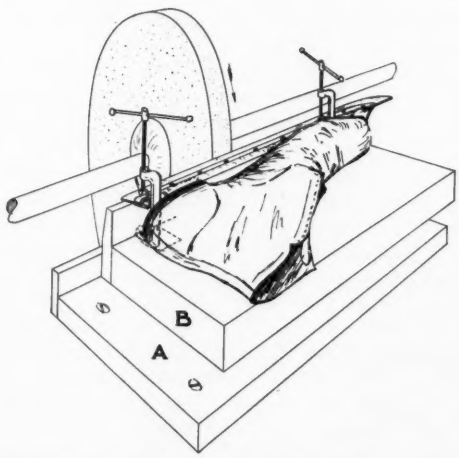



FIGURE 12.—HOME OUTFIT FOR GRINDING SKATES
The traveling frame, *B*, moves on the fixed frame, *A*.

(5) Pulpstone wheels. Three thousand dollars is the price of a pulpstone wheel for a paper mill.

The wheel (Figure 13) is six feet in diameter and over four feet thick, seemingly expensive but worth the money to the paper maker who uses it to grind wood pulp to a thin veil of fibers.

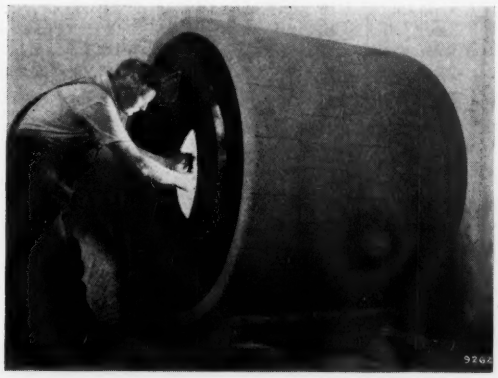


FIGURE 13.—PULPSTONE WHEEL

Obviously the chief uses of grinding wheels are not chemical but mechanical, so we will simply cite a few miscellaneous applications of everyday interest.

The famed straight edge of safety razor blades is produced by sharpening them with a grinding wheel whose grains are less than $^1/_{500}$ inch in diameter. Suede gloves are given their soft finish by passing the leather over a barrel-shaped silicon carbide grinding wheel. Gems are sawed with a thin disc of sheet metal, whose lower edge dips in a reservoir of machine oil and silicon carbide grain. Felt hats are finished by rubbing the sheet of felt over a form with sandpaper.

Anyone who regards sandpaper as a disappointing tool should try some having fused alumina grains standing on end. It is made by attracting the grains head-on to a strip of glued paper passing over an electrostatically charged plate. The grains are not only hard and tough but capable of many fractures, so that a keen abrasive face is maintained.

Fused alumina in grain form is incorporated with the paving mixture at the approaches to bridges, so that automobile tires can grip the pavement more reliably (Michigan Avenue, Chicago, at the Chicago River). Sand-blast nozzles are subject to unusual wear, so they are made of boron carbide or some other material high on the hardness scale.

Oddly enough, one of the most important recent advances in the abrasive field is a return to the diamond by the introduction of wheels in which a thin layer, about $^1/_8$ inch, of diamonds is coated on the grinding surface of the wheel. The cost seems high at first ($70 for a 6-inch wheel) but their efficiency in grinding cemented carbide machine tools is so great that their use is rapidly increasing. This is a fresh example of the see-saw competition that is constantly going on between Nature and the inventive power of man.

### THE LABORATORY IN THE ABRASIVE FACTORY

The scientific ability of a laboratory staff is called on not only for inventive research and precise control, but also in liberal measure to supply a customer with the best conceivable wheel for his need. It is an interesting outgrowth of modern research that the abrasive customer, often a very large manufacturer, has not only his own scientific staff but the scientific staff of his grinding-wheel maker and the similar staffs of other supplying factories at his service. The ramifications of industrial research coöperation are far greater than the ordinary man realizes, and scarcely anywhere is it better illustrated than in the abrasive industry.

### REFERENCES FOR FURTHER READING

JACOBS, "Abrasive handbook," Penton Publishing Company, Cleveland, Ohio, **1928.**
EARDLEY-WILMOT, "Abrasives, Part IV," Canada Department of Mines, Bull. 699, **1929.**
HEYWOOD, "Grinding-wheels and their uses," Penton Publishing Company, Cleveland, Ohio, **1938.**
TONE, "The quest for hard materials," *Ind. Eng. Chem.*, **30,** 232 (1938).
"Fifty years of manufactured abrasives," *Mfrs.' Record*, **110,** 22 (1941).
Trade publications obtainable on request from larger companies.

✦ ✦ ✦ ✦ ✦ ✦

The following description of the construction and operation of a miniature arc furnace for making silicon carbide is added with the thought that some readers with access to an arc-welding outfit may wish to carry this out as a special project.

## MINIATURE ARC-TYPE SILICON CARBIDE FURNACE

B. L. BAILEY, J. A. UPPER, AND E. A. BRADLEY

*Apparatus:*

1. 22 Fire bricks 9″ × 4$^1/_2$″ × 2$^1/_2$″, 2 of them to be cut in two crosswise
2. 2 Graphite electrodes 1″ in diameter × 12″ long arranged as shown
3. 2 Sheets heavy asbestos paper 15″ × 20″ approximately
4. 2 50-Ampere universal clips
5. 1 Ammeter and shunt, 200-ampere range
6. 1 D.C. voltmeter 0 to 150-volt range
7. 1 Arc welding unit (minimum capacity 200 amperes)
8. Various lengths of insulated cables

*Electrical Circuit:*

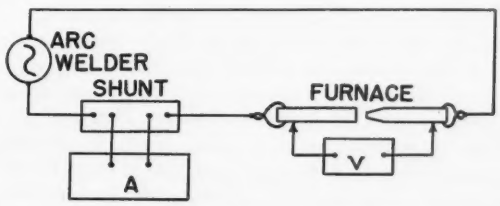



FIGURE 14.—CIRCUIT FOR MINIATURE SILICON CARBIDE FURNACE

*Mixture:*

Approximately 30 pounds of mix required

Materials:

Silica sand (99 per cent $SiO_2$)

Petroleum coke approximately 90 per cent fixed carbon and crushed at least as fine as small beans

Reaction:

$SiO_2 + 3C \rightarrow SiC + 2CO$

Mix in the theoretical proportions of six parts of carbon per ten of $SiO_2$. Calculate on basis of $SiO_2$ in sand and the fixed carbon in the coke.

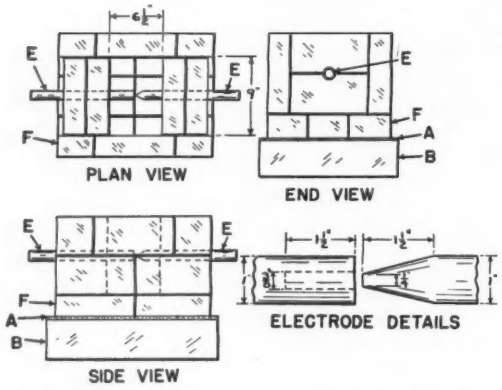



FIGURE 15.—CONSTRUCTION OF MINIATURE SILICON CARBIDE FURNACE

*B*—Wooden base; *A*—Asbestos paper; *F*—Firebricks; *EE*—Electrodes

*Furnace:*

1. Construction:
   The location must be where there is free ventilation.
   Details are shown in Figure 15. The firebricks are set up on a wooden box or base protected by two sheets of heavy asbestos paper and providing an interior space $6^1/_2'' \times 9''$ horizontally and 9″ deep. Grooves must be made in the end bricks to clasp the electrodes somewhat loosely.
2. Loading:
   Load mixture to just below the electrodes and tamp down.
   Wrap electrode tips with a sheet of paper to keep out mix, then fill furnace with mixture, tamping it well down as it is added. Add mixture above level of bricks and bring mixture to a peak.
3. Running:
   Pull adjustable electrode so that the two electrodes are not touching one another and start arc welder.
   Touch electrodes and draw an arc, regulate load by changing length of arc. Ignite gases approximately 5 minutes after the furnace is started. Run furnace approximately one hour and 15 minutes.

*Typical Operating Data:*

| *Time* | *Volts* | *Amperes* | *Kilowatts (calculated)* | *Remarks* |
|---|---|---|---|---|
| 1:15 P.M. | 43 | 110 | 4.7 | Furnace started |
| 1:20 | 45 | 98 | 4.4 | Gases ignited |
| 1:45 | 34 | 140 | 4.8 | Furnace burning on top |
| 2:15 | 41 | 102 | 4.2 | |
| 2:30 | 41 | 102 | 4.2 | Furnace cut out |

*Typical Pig:*

*A*. Layer approximately 3″ in diameter × $^1/_4$″ to $^3/_4$″ thick of green silicon carbide on inside and yellowish green fire sand on outside

*B*. Electrode

*C*. Void

*D*. Crust approximately $^3/_4$″ thick, 5″ long, and 7″ maximum diameter

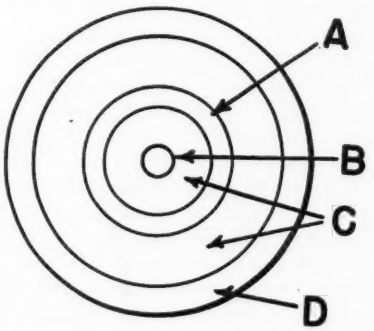



FIGURE 16.—TYPICAL SILICON CARBIDE PIG (VERTICAL SECTION)

## DEDICATED TO AMERICAN SCIENTISTS

DEDICATION of the Hooker Scientific Library to American scientists was announced by the *Friends of the Hooker Scientific Library* in the January issue of their official organ, *Record of Chemical Progress*. The dedication is in fulfilment of Dr. Hooker's desire, but was not publicly announced until the Library was able to establish a plan of technical literature services.

As another step toward making these services universally available a revised schedule of corporation and institutional membership fees was announced in the same issue of the *Record of Chemical Progress*.

The minimum fee for permanent membership, which has been $100 for any corporation or institution, remains at this level for laboratories having ten or more research workers. For smaller laboratories it is based on the size of the research staff with a minimum of $20 for one or two research workers. Above this level the schedule is:

| | | | |
|---|---|---|---|
| 3 research workers | $30 | 7 research workers | $70 |
| 4 research workers | 40 | 8 research workers | 80 |
| 5 research workers | 50 | 9 research workers | 90 |
| 6 research workers | 60 | | |

Any laboratory may designate persons on its research staff as individual life members, at $10 each, up to half of the laboratory's membership fee. Thus, a laboratory which joins at the $100 level may designate five life members. The signature of each life member, with the name of the institution in which he is employed, is mounted under a bookplate in the Hooker Scientific Library.

Full information may be obtained from the Hooker Scientific Library, Central College, Fayette, Missouri.

# A Grading System for General Chemistry

CHARLES B. DEWITT *John Tarleton Agricultural College, Stephenville, Texas*

SYSTEMS of grading are too often regarded as nothing more than comparative measurement of student achievement, but the time when they served only so simple a purpose has long since passed. The awarding of grades is a dominant factor in catalyzing student activity despite the prattle of those who talk in terms of "socialized," "integrated," and "attainable" education. Student grades are frequently used as a basis for estimating a teacher's efficiency, and in extreme cases, the teacher who gives a considerable number of low grades is censured more severely than the students who receive them.

The study of chemistry involves a dual learning process. The student must absorb a large amount of information and master numerous facts which he can present to the instructor on demand. He should also learn to apply his information to situations or problems that are somewhat different from those that have been used for teaching illustrations. Incidental to attaining these objectives, he should learn something of the methods for finding additional information, and he should be encouraged to correlate his chemistry with his work in other courses. A satisfactory grading system should include means for measuring progress toward all of the announced objectives of the course.

The classical percentage system provides too narrow a margin between minimum passing scores and alleged perfection. Schemes based on distribution curves derived from examination scores tend toward a reduction of the minimum requirements. A restatement of the meaning of the various grade marks in terms only a little different from those found in college catalogs suggests a means of avoiding the objections. The grade of *D* may be interpreted as acceptable but not satisfactory. Students who receive this grade are not encouraged to take advanced work, and a large number of *D* grades usually bars a student from graduation. Students who make *D* in general chemistry usually possess a scanty store of information, and few of them show any ability to apply the little knowledge that they have acquired. The grade of *C* can be adequately defined by the word satisfactory. Inspection of examination papers will often show that the *C* student has depended largely on memorization and that he is weak in the application of principles. The grade of *B* represents some degree of superiority which is most often attained by the hard working plodder or by the brilliant student who is satisfied with a mediocre effort. The first type of student may earn a *B* by intensive memorization with some application, while the second student is more likely to earn it by use of his reasoning ability. The top grade of *A* then becomes a mark of true mastery which requires both superior ability and hard work.

Many students of general chemistry have been observed to spend so much of their time and effort in attempting to master the more difficult topics that they have neglected the simpler fundamentals. In such a case, the mediocre student becomes completely discouraged and his more able fellow becomes disgusted. The grading system used by the writer has been devised to secure maximum effort from both weak and strong students when they cannot be segregated in different sections. It depends primarily on a clear demarcation between the acquiring of information and the application of principles.

A discussion of an examination will explain the principal features of the system. The examination is divided into two parts labeled Part A and Part B. There might be eight essay-type questions in Part A and these might be graded on a basis of ten points each. They would be questions of information and the answers could be learned by memorization of the material from the textbook and lectures. The students are told that this constitutes a qualifying test without which Part B has little value. A grade of 70 on Part A will give a student a passing grade on the examination even if he omits Part B altogether. A perfect score on Part A, however, will give him nothing better than a low *C*. Higher grades are dependent on the answers to the questions of Part B. These questions cannot be readily answered with memorized material alone. They include the more difficult principles, application of principles to new situations, and processes or problems that require a combination of principles that may not have been used together in the classwork. They always include one or more questions that only the very best students can be expected to answer. Since no individual is expected to answer all of them, they can be made to cover the widest variety of topics and a considerable range of difficulty. In answer to a student's question about the method of scoring, one class was told that if Part A were satisfactorily handled, answers to two questions from Part B would guarantee a high *C* on the examination and that three correct answers would earn a grade of *B*. If a student answered four questions, his grade would probably be *A*, and if any individual answered all six questions in the allotted time, it would be a miracle. No miracles have been performed. Most problems are put in Part B questions when they are first studied, but the simpler ones may appear in Part A later in the semester.

The problem of the student who falls below the requirement on the information questions but who works some of the problems offered a little trouble at first. It was solved by transferring points from the second part of the examination to the first part at a reduced value. Thus a student who earned a score of 65 on information and 25 on applications would receive the

same grade as one who scored 70 and 15 on the two sections. This practice has resulted in a marked decrease in the tendency to slight the fundamentals. Some additional flexibility is provided by allowing extra credit on a few items. If a question asks for two equations for the preparation of chlorine, the student who gives four will receive extra credit. Numerical answers to problems are not required, but the work must be carried to such a point that it can be completed with the direct operations of arithmetic. The student who obtains a numerical answer receives extra credit, amounting to about ten per cent of the problem's nominal value. Use of the slide rule is encouraged.

Two other points are worth mentioning in connection with the determination of semester grades. Neat and orderly papers on both examinations and daily work can earn the student a bonus that may change his grade from a high *C* to a *B*. It cannot raise a grade that is below passing. Collateral reading is encouraged by a similar arrangement. By doing sufficient reading in approved books or periodicals, a student may raise a passing grade by one letter.

Although there is nothing spectacular or revolutionary about this procedure, is has brought about an improvement in the conditions it was designed to meet. The amount of work done by the best students has been markedly increased. The weaker students have been helped to concentrate on those portions of the course that they could master, and the number of failures has decreased. Finally, operation of the system seems to have helped a little in bringing about earlier elimination of the incorrigible loafers.

## LABORATORY EXPERIMENTS INVOLVING AMMONOLYSIS OF ESTERS[1]

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*Wayne University, Detroit, Michigan*

IN THE courses of organic chemistry given at Wayne University, certain sequences of experiments are set up in which the student uses his own preparation to make the next. One of these series is that of ester-amide-amine. For some years, ethyl acetate was the initial ester, but for various reasons it was decided to alter the procedure by substituting others. It soon became apparent that many esters could not be ammonolyzed according to the directions in the manual.

Since it seemed desirable to know which of them would or would not react, quantities of ester and concentrated ammonia in molar ratios of 1:3 were placed in a 250-cc. distilling flask which was stoppered and allowed to stand for at least two days, with occasional shaking. The mixture was then heated and the portion distilling above 160° collected in a beaker. This crude product was not further purified.

Twenty-five different esters were tried, most of which were student preparations. Of these, the following gave yields of 73 per cent to 87 per cent: ethyl, *n*-propyl, *n*-butyl, isobutyl, and *n*-amyl formates, methyl and ethyl acetates, methyl propionate, and methyl butyrate. *n*-Propyl acetate, ethyl propionate and butyrate, and methyl valerate gave yields between 30 per cent and 62 per cent. The rest showed little or no reaction as evidenced by the amount of amide formed.

Certain general conclusions were readily apparent: (1) methyl esters are the most reactive, (2) the activity decreases with increasing molecular weight of alcohol or acid, (3) esters of iso or secondary alcohols and of iso acids are less active than esters of normal acids and alcohols, and (4) all formates investigated ammonolyzed readily.

To obtain a satisfactory yield of amide from an ester such as butyl acetate, it is not practicable to let the mixture stand for several weeks nor to heat it under pressure. If these relatively inert compounds could be converted to the methyl esters, a reasonably rapid reaction with ammonia might be expected. The reaction

$$RCOOR' + CH_3OH \rightleftharpoons RCOOCH_3 + R'OH$$

is stated by various authors to be catalyzed by such things as pyridine, alcoholates, sodium, and traces of NaOH.

A number of experiments on butyl and isoamyl acetates showed sodium methylate to be the most efficient catalyst. A small piece of sodium was dissolved in a half mol of methanol and a third of a mol of the ester was added. After 24 hours, 1.5 mols of concentrated $NH_4OH$ were added and the mixture was set aside for two days with occasional shaking. Upon subsequent fractionation, yields of from 40 per cent to 68 per cent of amide were obtained from such esters as *n*-butyl and isoamyl acetates, *n*-butyl and *n*-amyl propionates, and *n*-propyl butyrate, which without previous alcoholysis will form little or no amide. Overall yields are necessarily smaller using these esters. Although an 85 per cent yield can be obtained from methyl acetate, propionate, or butyrate by careful technic, the less reactive esters of these acids form an equilibrium with $CH_3OH$, the degree of which seems to vary with different esters.

In view of the results obtained, it should not be difficult to adapt a wide variety of esters to the laboratory preparation of amides of five carbon atoms or less. Where time permits, alcoholysis of an ordinarily unreactive ester with $CH_3OH$ previous to ammonolysis will emphasize to the student the fact that equilibria are a very important characteristic of organic reactions.

[1] Presented before the Division of Chemical Education at the 102nd meeting of the A. C. S., Atlantic City, New Jersey, September 10, 1941.

# Dust Explosions

JOSEPH B. FICKLEN[1]

*The Travelers Insurance Company, Hartford, Connecticut*

SOME years ago practically everyone who attempted photography at night used magnesium powder for illumination. The brilliant light produced by burning this powder was the simplest light source of sufficient intensity to take good night photographs. However, the terrific heat of some of these magnesium fires produced burns on careless photographers and often resulted in severe property damage. In recent years the use of magnesium powder by the general public for illumination in photography has been largely superseded by the use of photoflash or photoflood bulbs. Hence, many persons today are not aware of the disastrous effects that can be produced by the quick fire or explosion resulting from the ignition of magnesium powder. In fact, one type of incendiary bomb used in the present war depends on the burning of magnesium for its destructiveness.

Recently the hazards of magnesium dust and even of large bits of magnesium, such as shavings, turnings, and borings, have been brought forcibly to the attention of industry. This is due to the ever-increasing use of magnesium metal in the construction of airplanes and of various machine parts where light weight is of primary importance, which has been accompanied by a number of serious fires and explosions.

Here are the details of a magnesium dust explosion: In a certain plant, dust from the grinding of magnesium alloy castings was exhausted by a fan through a duct about 40 feet long and then was wet by a spray of water. The water spray *should* have been close to the grinding wheel. A casting had been made which had a wire nail in it to hold the core upright. When a portion of the casting had been ground off, the grinding wheel struck the wire nail and sparks were produced which ignited the dust. An explosion followed which demolished the exhaust duct, air washer, and fan housing, and broke about two hundred panes of glass in the windows of the plant.

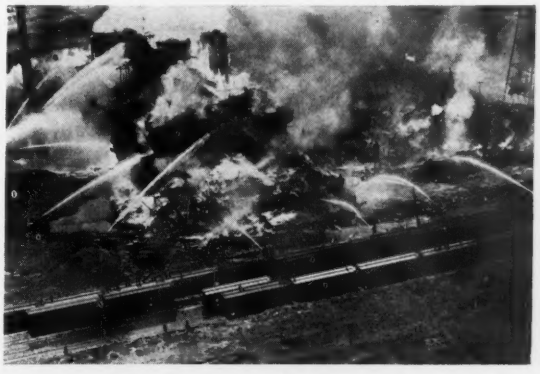
The manufacture of another metal dust—aluminum dust or "powder" as it is usually called—also may involve a considerable explosion hazard. The sheet aluminum is powdered in stamping machines and then is screened to the desired size. Not long ago an explosion occurred in a stamping and screening department of an aluminum "powder" plant. The force of the explosion blew off the roof and shattered the side walls. The two employees inside the building at the time of the accident were injured so severely that they died later in the hospital. Water for fighting the fire was available but was of no use, because it was known that the application of water to burning aluminum dust is positively dangerous.

[1] Present address: 727 South Oakland Avenue, Pasadena, California.

The same danger is present when using water to extinguish magnesium fires. Magnesium and aluminum react with water to produce hydrogen and the corresponding hydroxides. This reaction is very slow at ordinary temperatures but the rate of reaction increases rapidly as the temperature rises. This explains the extreme violence of the combustion of wet aluminum or magnesium. The hydrogen produced introduces an additional hazard on account of its flammability. Much safer extinguishing materials have been suggested, such as powdered graphite or talc, fine cast-iron borings, and similar inert material. Sand is not particularly effective, especially in the case of magnesium; certain tars are more effective

Practically everyone knows that the majority of dusts arising from the handling or processing of various grains, seeds, and agricultural products can form explosive mixtures in air. Certain finely divided metal dusts, as discussed above, as well as the dusts from some of the synthetic resins also can form explosive dust clouds in air.

Many of us have read of grain elevator explosions, but few of us realize how disastrous they can be. For example, a few years ago a dust explosion and fire occurred in a grain elevator in Chicago. Nine persons were killed and about thirty others were seriously injured. The property loss was estimated at $3,500,000. Not only was the grain elevator in which the explosion took place seriously damaged, but in addition three other grain elevators nearby caught fire and were almost completely destroyed. Only a small amount of the grain stored in any of the four elevators was salvaged.



*Courtesy of the U. S. Department of Agriculture*

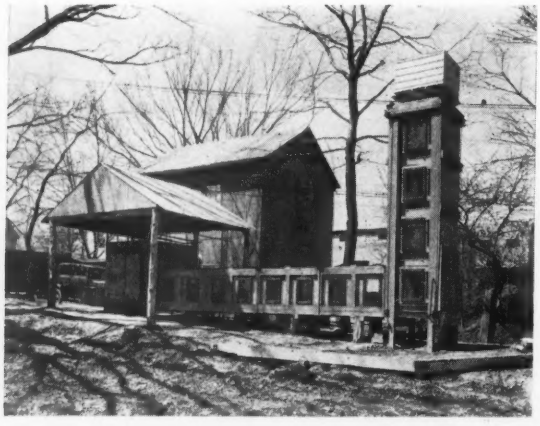
FIGURE 1.—RESULTS OF A DISASTROUS GRAIN ELEVATOR EXPLOSION

Various devices have been built for showing qualitatively that a dust will explode and for evaluating the

relative amount of damage to be expected from explosions of different dusts. All this information is of great value in devising suitable precautionary measures. An apparatus has been developed which will demonstrate whether a certain dust in air is explosive. It consists of an electric motor and a metal box or "explosion chamber" provided with a hinged cover. Inside the box there is a piece of leather fixed into the motor shaft which extends through the wall of the box. A sample of dust is placed on the leather, and when the motor is started the dust is thrown into the air inside the box. An ordinary spark plug placed in the side of the box provides a source of ignition for the dust cloud. The explosion pressure, flame, and gas are vented by the hinged top which flies up when the explosion occurs.

In order to get data on the intensity of the explosion, certain factors must be determined more accurately than is possible merely by the qualitative test described above. For example, the fineness of the dust and the concentration of the dust in the air have a bearing upon the maximum pressure developed and also on the rapidity with which this pressure is built up. Suitable apparatus has been devised for carrying on such experiments on a laboratory scale.

A setup which approaches nearly actual plant operations is the one used by the United States Department of Agriculture at the Arlington, Virginia, Experimental Station. This was built primarily to study the ways by which dust explosions may be rendered harmless. It appears that pressure built up at the time of an explosion may produce an undue spread of flames and also secondary explosions. These secondary explosions may be caused by an ignition of dust thrown into

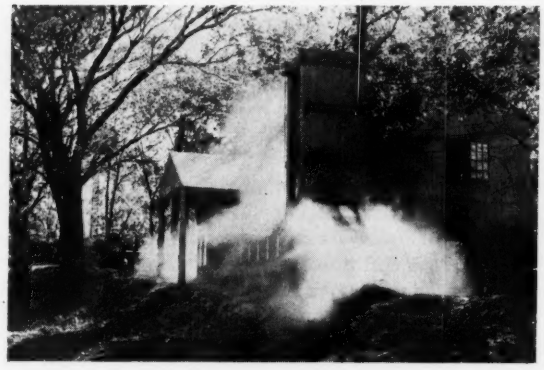


*Courtesy of the U. S. Department of Agriculture*

FIGURE 2

U. S. Department of Agriculture Experiment Station, Arlington, Virginia, showing special equipment erected for the purpose of studying the venting of dust explosions

the air (from beams or other parts of a building) by the first explosion, and may play a major part in the loss of life and damage to property. This setup—Figures 2 and 3—consists of a room, a gallery, and a tower erected and connected as shown. Bowls for holding dust are located throughout the structure as desired, and the dust is thrown into the air by means



*Courtesy of the U. S. Department of Agriculture*

FIGURE 3

A typical dust explosion being vented without breaking glass in the fixed glass windows of the tower and gallery

of compressed air. Ordinary glowing electric-heater coils are used for ignition. Pressure gages are provided at various points to determine the explosion pressures developed. Openings of various sizes can be arranged along the entire unit.

Taking into consideration (1) the maximum pressure developed by explosion and (2) the rate of pressure-rise not only for different dusts but also for various concentrations of the same dust, the United States Department of Agriculture has graded more than 100 dusts for explosibility. Some of these dusts, arranged in order of their decreasing explosibility (on basis of 100), are:

| | | | | | |
|---|---|---|---|---|---|
| 1. | Cellulose | 90 | 8. | Potato starch | 57 |
| 2. | Lycopodium | 73 | 9. | Wheat flour | 55 |
| 3. | Elevator dust (Corn) | 70 | 10. | Alfalfa | 35 |
| 4. | Corn starch | 70 | 11. | Smoking tobacco | 20 |
| 5. | Bituminous coal | 65 | 12. | Iron | 17 |
| 6. | Magnesium | 65 | 13. | Anthracite coal | 0 |
| 7. | Aluminum | 60 | | | |

All this study and research have led to the formulation of protective regulations both to eliminate dust explosions and to render them as harmless as possible when they do occur.

In considering the possibility of dust explosion in a given case, one point stands out as of primary importance: Can the process be carried out, or the combustible material be handled in such a manner, that no dust is developed? If so, then, of course, no hazard from dust explosion exists. Sometimes the development of dust in a process is entirely unnecessary. However, if a combustible dust is unavoidably present it should be confined in such a way as to prevent its escape into the atmosphere. Open storage bins and bins with direct connections permit the rapid spread of flame in case of ignition, and thereby extend the area in which

the damaging effects of an explosion may be manifested. Preventing the spread of the explosion and fire from one bin or storage space to another is of prime importance.

Cleanliness and good housekeeping are most important in dust-explosion prevention. Serious explosions, as pointed out above, result when dust from ledges or beams is thrown into the air, either by jarring or by a primary explosion.

In some processes the use of an atmosphere containing an inert gas, such as carbon dioxide, provides protection in grinding and pulverizing operations. For example, when the oxygen content is reduced to approximately 12 per cent, in grain-grinding operations, complete protection is afforded. The reduced oxygen content (as the result of the addition of the inert gas) prevents the ignition of the dust cloud in the grinding machine, and also prevents the spread of fire through the conveyors or elevating machinery.

Dust explosions have resulted from sparks produced by foreign substances such as metal and rock, inadvertently included with material being processed. In grain-handling operations, especially, it is sometimes hard to exclude all foreign material, and pebbles and bits of metal, striking against parts of the equipment, have produced sparks which have ignited grain dust and thus have caused explosions. Screens placed in the grating over receiving pits often have stopped large pieces of foreign material from going into the pits with the grain. However, pneumatic and magnetic separators are usually needed before each grinding operation to intercept and remove the smaller objects.

All electrical equipment in dusty locations should be given special consideration. The National Electrical Code for Hazardous Locations specifies the type of equipment that should be used in these places. No sparking or spark-producing machinery, such as motors with commutators, knife switches, etc., should be permitted where explosive dust may be created. Other sources of danger are unprotected portable lamps. These and all other electric lamps in dusty exposures should be provided with outer dustproof globes; and if they are likely to be struck or moved, the dust-tight globes should be surrounded by heavy wire guards, for additional protection.

Static electricity appears to be a prominent cause of dust explosions, and considerable attention has been given to the development of control methods of this hazard. It has been shown that if the relative humidity is above 60 per cent, static electrical charges do not collect to any appreciable extent. However, in many manufacturing processes it is impossible or impracticable to maintain such a high relative humidity. Provision must then be made for the removal of static charges on machinery handling combustible dusts or operating in parts of the plant where such dusts may be present. Electrical grounding of stationary objects usually is relatively simple, but moving objects, such as belts and pulleys, often present a serious problem.

The type of dust involved and the shape of the room are among the factors which must be taken into consideration when calculating the necessary area of hinged doors or windows intended to prevent structural damage to the building in case of an explosion. With grain elevators, for example, good practice requires a "venting area"[2] of at least one square foot for each 80 cubic feet of room volume. Such venting areas usually take the form of nicely balanced windows or doors. Tests have shown that, in general, even single-strength glass panes, in ordinary sliding windows, will withstand, before they blow out, a pressure sufficient to cause serious damage to other parts of a building. The use of large areas of scored glass windows in lieu of hinged vents has been investigated. However, it has been found that the pressure required to break scored glass is much greater than that required to swing open suitable window and wall panels.

The extinguishing of a fire involving combustible dusts calls for extreme care. Sometimes the turning of a full stream of water on a dust forces a dust cloud directly on to the fire, thereby causing an explosion.

Generally speaking, wetting of explosive dusts with a spray of water is preferable to using the full pressure from the hose. Very dangerous explosions may occur after a general fire has started. For example, the concussion resulting from the falling of floors or the dropping of the bottom of a storage bin may force a cloud of dust on to the fire. Explosions have taken place when firemen have attempted to remove the contents of bins or other enclosures in an effort to determine whether the original fire in the bin had been completely extinguished. The dust clouds thus produced readily ignited upon coming in contact with flames. Such dusty contents of bins should be thoroughly drenched before removal. The possibility has already been mentioned of additional trouble being caused by chemical reaction between water and aluminum or magnesium dust.

Plants that have combustible-dust exposures should be systematically and periodically inspected by firemen. This enables the firemen to become familiar with structural features of the buildings and the precise nature of the exposures. This knowledge is helpful in working out a plan of fire fighting that will more adequately protect the firemen.

The above-mentioned hazards of combustible dusts and the precautions to be taken have been developed through extensive observation of actual happenings, coördinated with research work. However, there is still great need for more exact data on many of the points touched upon. Also, many new processes are coming into use each year that create new combustible-dust hazards. There is a vast amount of work still to be done in this interesting chemical and engineering

[2] The size of opening necessary to permit harmless escape of gases which may result from explosion. The neck of a wide-mouthed bottle offers sufficient venting area for an explosion of oxy-hydrogen mixture. A narrow-mouthed bottle might be shattered by such an explosion.

field. It is safe to predict that such work as carried on by the United States Department of Agriculture and other government and state groups, as well as by various insurance bureaus, insurance companies, and other private organizations, will continue for many years to come.

## (JULIUS) ROBERT MAYER (1814–78)

***(Frontispiece)***

THE physical sciences are based on the laws of "conservation of mass" and "conservation of energy." These fundamental principles have a long history; their beginnings go back to antiquity. During the adolescence of chemistry and physics they emerged in fragmentary form, but the clear and generalized statements of these, the highest of all natural laws, are credited by most authorities to Lavoisier and to Mayer.

The story of these men has been told too often to warrant repetition, but certain points are worthy of emphasis. Neither of them was a professional scientist. Lavoisier took his degree in law and made his living as a financial agent and public official. Mayer, a practicing physician, never had more than a lower school course in physics or mathematics. The self-taught man often has the advantage of lacking the blind spot that comes from ingrained professional pre-judgments, but he also runs the risk of being regarded with suspicion by those who cling to the traditional form of thought.

Lavoisier, a rich man, lived in the scientific capital of his country; he was a respected member of the Academy of Sciences, whose meetings and publications were always available when he wished an audience or readers.

THE MAYER MONUMENT AT HEILBRONN ON THE NECKAR

Mayer, a man of modest means, lived in the small town of Heilbronn, isolated from scientific contacts. His first paper on the energy principle was permanently pigeonholed by the editor, a physicist; a revised draft published in Liebig's *Annalen* aroused no interest, and years passed without recognition that Mayer had published anything of importance. This neglect and isolation so affected his sensitive nature that he had to enter a sanatorium for bodily and mental care. Here he received mostly ill-treatment, including a strait jacket. His ideas were said to lack originality—some said they were ridiculous and unscientific. They were pirated so competently that his protests resulted in his gaining a reputation among his townsmen as a megalomaniac laying claim to the discoveries of others. Efforts to extricate his brother from a foolish political scheme almost brought Mayer before a firing squad as a spy. Such tortures undermined him; after a sleepless night he jumped from a window, thirty feet from the ground, and broke both legs. A false report that he had died in an insane asylum persisted for many years. On one occasion when he lectured before a prominent scientific society, a newspaper raised the question why such a reputable organization should give a lunatic a place on its program.

Mayer, unlike Lavoisier, was not a combative soul; he had little of the crusading spirit, and though he was convinced of the significance of his doctrines, he preferred to let truth and time enter the lists as his champions. Among the scientists, Tyndall was the only one who actively fought for him as the true author of a principle that virtually transformed the foundations of science. His chief honors came from foreigners: the Copley Medal and the Poncelet Prize. His alma mater, Tübingen, conferred an honorary doctorate, the Academies at Munich and Basle elected him to membership, but these were small compensations for what he had endured.

Lavoisier, who included light and heat among the elements, would have rejoiced in Mayer's teachings. Sacrificed by the politicians to the maniacal stupidity of the *sans-culottes*, Lavoisier's memory is commemorated in Paris by a stately monument. This, too, has in it an element of injustice, for it has now been proved that the head of the statue is not a likeness of Lavoisier, but was copied from a bust of Condorcet, with whom Lavoisier was not on cordial terms.

Mayer's last few years were comparatively peaceful, but there can be little doubt that his life was shortened by intrigue, jealousy, and false accusations. "As we stood around his grave a bitter feeling came over us: Robert Mayer was misunderstood and insulted, until he was broken bodily and mentally. At last a foreigner brought about a change in his treatment. But now he is at rest; he has reached his goal."

An impressive statue has been raised to Mayer. It stands before the city hall of his home town. Heilbronn has little to offer the tourist and not many American scientists have seen this memorial, or the collection of personal souvenirs in the neighboring town museum.

Mayer's life was embittered by the things he hated: contention and argument. Pilloried by the thoughtless public and by those who should have welcomed him as a gifted fellow-scientist, he drew from the depths of his sensitive soul when he wrote of the Darwinian theory: "Of course there is a struggle for existence, but it is not hunger, nor is it war, neither is it hate that preserves our world—it is charity."

*—Contributed by Ralph E. Oesper,*
*University of Cincinnati*

# Chemistry in the Engineering Defense Training Program of The Pennsylvania State College[1]

ARTHUR ROSE

*The Pennsylvania State College Extension Services, State College, Pennsylvania*

THERE is no need to emphasize the present importance of chemistry in national defense. This subject usually brings to mind subjects such as chemical warfare or ordnance production and inspection, but a mere glance at the defense priorities lists indicates the more general importance of chemical knowledge in the present emergency. The highly industrialized nature of the state of Pennsylvania and the urgency of defense production have forced The Pennsylvania State College Extension Services to enter into an intensive defense training program.

Careful surveys of industrial man power requirements for Pennsylvania industries indicated the urgent need for men with college level technical training of a specialized nature. During the winter and spring of 1940–41 many thousands of students were engaged in evening training courses in drafting and various specialized phases of mechanics, metallurgy, fuel technology, and related fields in order to prepare themselves to fill openings in defense industries. Chemistry instruction played only a small part in these activities.

The experience with the winter and spring program showed very definitely the need for a proper basic training in the fundamentals of engineering and science. This led to the organization of the full-time summer Introductory Engineering Subjects (IES) program for recent high-school graduates. This program proposed to create a reservoir of men with minimum college level training in drafting, mathematics, mechanics, physics, and chemistry. Such training would improve these men markedly for numerous semi-technical industrial jobs, and also give them the necessary background for specialized training and work.

The survey showing the need and feasibility of this type of training was made by the regular district representatives of the long established extension service. These representatives are residents of their districts, who are familiar with local industries, needs, and facilities, and also with the problems involved in extension education on the college level. The Pennsylvania State College Extension Service is probably unique in being organized on the principle that the organization and operation of extension centers should be carried on by district representatives, while the approval of instructors, course content, standards, and supervision of instruction is done by a member of the regular staff of the resident department. The wisdom of this coöperative arrangement was emphasized by the success of the IES summer program.

As finally organized and put into operation, the program was carried out in about 100 communities throughout the state, with a total of over 2500 students. In a few centers a considerable proportion of the students dropped out to accept employment, but it is estimated that 80 per cent of the students originally enrolled completed the work satisfactorily.

The work continued for a ten-week period, beginning in June as soon as regular high-school or college facilities were available. College facilities were rented whenever possible, and in other cases high schools with suitable facilities were used.

Since the students in the IES program were preparing for industrial work, the schedules were based on a 40-hour week. Actual classroom and laboratory work took up a total of 29 hours and the remainder was used for "supervised study" periods. The classroom and laboratory time included 8 hours per week of physics, and 5 each of mathematics, mechanics, drawing, and chemistry, as well as one hour of engineering coördination lecture. Three hours per week were devoted to chemistry laboratory work and two were devoted to classwork. Every student was required to take part in all the subjects listed.

It can be seen that such a program might easily overwhelm the average student; in fact a freshman student in a good engineering college might be congratulated if he carried such a program satisfactorily. Instructors were urged to try to avoid overburdening the students. It seemed better to have them leave the course with complete confidence regarding a few important concepts than to increase the course content and have the students lack confidence.

To direct the efforts of both students and instructors a short list of major objectives was prepared. These included: (1) development of a working knowledge of symbols, formulas, equations, and atomic and molecular weights to make simple calculations, (2) ability to recognize the difference between elements, compounds, and mixtures to the extent that simple diagrams could be correctly drawn to show arrangement and combination of atoms and molecules in common materials, (3) ability to recognize the difference between a metal and a non-metal and use the periodic table to classify common elements on this basis, (4) ability to use a handbook or textbook.

The content of the course differed from the usual elementary college chemistry course in the following respects:

(1) Complete elimination of work on atomic structure, and of any rigorous or logical develop-

[1] Presented before the Division of Chemical Education at the 102nd meeting of the A. C. S., Atlantic City, New Jersey, September 9, 1941.

ment of atomic, molecular, or ionization theories.

(2) Provision of motivation for the work on oxygen and oxidation by using combustion and blast furnace reactions as examples. This served to introduce acidic and basic oxides, acids, bases, neutralization, salts, and slag formation.

(3) The lessons on hydrogen similarly emphasized hydrogenation, reduction of metallic oxides by CO and C as well as hydrogen, and the action of acids on metals led to metallic corrosion.

(4) Great reduction of the proportion of time given to conventional studies of non-metals and their compounds.

(5) Devotion of the entire latter half of the course to fuels and combustion, rubber, solvents, resins, and plastics, the essentials of the chemistry of metallurgy, cements, lime, and plaster.

(6) Continued reintroduction and emphasis on the major objectives listed above to prevent the course from degenerating into mere description.

The problem of rapidly assembling a staff of chemistry instructors capable of teaching a college level chemistry course in 100 scattered centers was serious. In some cases an instructor divided his time between two adjacent centers, and in this way a group of 70 instructors proved sufficient to carry out the program successfully. They were drawn from colleges in 14 states and included 29 professors and department heads, as well as six high-school chemistry teachers who were all especially qualified for the work by training or experience.

All instructors attended a preliminary series of conferences in State College which dealt with general matters such as the background, organization, and objectives of the program as a whole and with the content, objectives, and potential difficulties of the separate subjects.

Laboratory work in extension services involves complex problems of facilities and supplies, but it seemed particularly desirable in this case, and after lengthy discussion and careful consideration it was decided to include individual laboratory work in the course.

Every laboratory was inspected by a member of the supervisory staff before classes commenced and arrangements were made to supply necessary equipment. Except in a few instances the high-school laboratories were adequately equipped, although instructors were sometimes driven to extremes, such as chipping marble off a tombstone!

The coördination and control of the instruction in chemistry were achieved largely through the efforts of a group of five experienced and responsible college chemistry teachers who acted as district supervisors. Their duties ranged from the delivery of sulfuric acid and litmus paper to classroom and laboratory visitations with subsequent advice and inspiration to discouraged instructors. Each supervisor had about 20 centers in his territory, and managed to visit most of them every week. A weekly meeting of all chemistry supervisors provided for general coördination and contact with the college itself.

The actual operation of each center was delegated to an administrative head who was always an official or responsible teacher of the local high school or college. This administrative head was familiar with the local problems and facilities, and was therefore given the responsibility for coördination of efforts of various instructors and the smooth operation of the center. The administrative head was in turn responsible to the district representative.

A certain amount of uniformity was also achieved by giving two uniform hour tests during the program. The first was of the conventional type dealing almost entirely with the major objectives listed above. The second or final examination was of the objective type, with emphasis on retention of descriptive matter. It is hoped to prepare a more complete report on the results of these tests at some later date, since they offer excellent opportunity for comparison with psychological, aptitude, and other subject-matter tests given to the same group of students in this program.

A number of supplementary types of instruction were coördinated with the usual classroom and laboratory instruction. These included general activities such as: (1) supervised study periods at which one or more instructors were present to direct and aid students, (2) a "weekly engineering lecture" by a senior staff member of the college to orient the students, (3) an aptitude and testing program coördinated with a placement program, emphasizing the importance of the student's own efforts in placing himself, (4) visual aids in the form of films and demonstrations, and, (5) emphasis on the use of handbooks and the slide rule.

Only students who were not planning to enter college were admitted. IES students were first recommended by their high-school principal and their applications were then acted upon by a committee of the engineering faculty. An effort was made to interview as many as possible before allowing them to register.

The persistence and willingness to work and the enthusiasm of the average student in the program were truly remarkable. A few students showed signs of immaturity but the great majority kept the entire staff continually on the alert. It was this student enthusiasm, coupled with the careful and conscientious work by teachers, that made the entire program succeed in spite of limited time.

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Fact finding is one of the least developed of American national resources.—OWEN D. YOUNG

# Visual Aids and Training in the United States Army

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COGNIZANCE is taken in the Army of the fact that when a training job is being done the learner is getting the new idea through the medium of his five "antennae of learning"—the physical senses. An attempt is made to cause the soldier to make use of as many senses as possible in learning a job, thus effecting greater speed in learning and better retention of knowledge gained. It is also recognized that of the five senses, considered individually for purposes of comparison, it is easier for the learner to absorb basic instruction in a new subject through use of his sense of sight. Much emphasis is therefore placed on visual aids in the huge school we call the Army.

The liberal use of charts and blackboards is encouraged for certain classroom instruction; for example, the outlining of tactical situations preparatory to going out "in the field" to simulate combat. Projection of film strips, or picture sequences printed positively on 35-mm. film, is employed to some extent to aid the instructor in the early phases of instruction, as in disassembling, assembling, care, and cleaning of weapons. However, of all the visual aids available, one of the most effective is the 16-mm. sound training film, many of which are now available for Army training.

Let's follow Joe Doakes for part of his tour of duty. Inducted in the U. S. Army, Private Doakes is taken to a reception center for a few days. In the short time spent here in a general checkup on his military potentialities, there is normally time for a training film or two; such films as may be shown here would deal with indoctrination in such subjects as personal hygiene and sanitation. Joe will begin to link up his school and home training with that of the military.

The replacement training center, so-called, normally occupies the next eight weeks of Private Doakes' existence, and here films on many subjects are available for use in the training of the company to which he is assigned. Let us say the company training schedule on a particular day calls for instruction in sex hygiene. A three-reeler in sound, lasting twenty-six minutes, may be used as a teaching aid for the instructing officers, whose instruction is correlated with that of the film. In this important subject a company officer, medical officer, and a chaplain normally each present a portion of the instruction.

Very early in the soldier's basic training attention is given to infantry drill, starting with the smallest combat team—the squad. Comparing the training of the army squad with that of the football squad, one notes many points of similarity: basic drilling helps to coordinate the muscle and mind of the individual squad member, establish in him a team spirit and a willingness to obey orders from proper authority instantly, willingly, and without question. As training films have been used by football coaches, so have they been employed by Army "coaches"—the officers and noncommissioned officers charged with making soldiers from raw recruits. For example: Private Doakes, 1st squad, 2nd Platoon, Company B, Replacement Center Training Battalion, Camp X, along with the rest of his particular company, witnesses a one-reeler in sound explaining and demonstrating in a straightforward, understandable manner the basic principles of close order drill as they pertain to the squad. He is thus informed of the *why* and gets a rough idea of *how* before he gets out to *do* the job.

Having been a road construction worker in civilian life, Doakes, after completing the eight weeks at the replacement training center, is assigned to an engineer company. At a particular stage of training the unit is being instructed in the building of pontoon bridges for river crossings. A thirty-minute three-reeler in sound is available as an aid to the instructor charged with this training. And so the movies definitely do their part not only in entertaining the soldier for improvement of his morale, but also in training for improvement of his efficiency.

The War Department's Signal Corps is charged with the preparation of training films; they in turn obtain technical advice regarding a particular subject from the other branches; *e. g.*, the Corps of Engineers, Air Corps, Infantry, Chemical Warfare Service, etc. Men with sound instructional experience have prepared the scenarios for the technical experts to work upon. The skilled personnel of the Signal Corps have been augmented by civilian soldiers, both officers and selectees, with civilian experience readily adaptable to the job at hand. Yes, Hollywood personnel are hard at work for the Army; movie producers and technicians of all kinds now wear the olive drab and khaki.

Use is made of visual aids such as have been mentioned in this article primarily to expedite and standardize the explanation and demonstration phases of instruction. As in civilian educational work visual aids are considered as *aids* to the instructor and by no means are they construed to represent complete instruction. Further instruction and the soldier's application to the job normally follow immediately. Army doctrine has it that films should be properly integrated with the training schedule and should not be shown at times other than those at which they can improve the efficiency and effectiveness of the instruction being given.

*High-School Chemistry*

# The Home Preparation and Preservation of Food

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MANY good cooks would doubtless be surprised to learn how many cooking processes involve principles that are part of the science of chemistry. Many chemists might be even more surprised, if they began to ponder the subject, to know how much of their science is applied in the kitchen.

Only a few of the materials used in cooking are single chemical compounds. Water, sugar, starch, baking soda, cream of tartar, and salt are among the most common. Since salt tends to take up moisture or, as the chemists might say, is hygroscopic, small amounts of materials such as calcium carbonate, that is precipitated chalk, magnesium carbonate, or tricalcium phosphate, are sometimes added to the salt so it will pour freely. Many of the materials used in cooking appear homogeneous to the naked eye but they may be easily proved to be mixtures by separating them into their component parts. Flour is essentially a mixture of carbohydrate (starch), proteins (glutenin and gliadin), moisture, and a small quantity of inorganic salts. If flour is mixed with a small quantity of water and kneaded, a stiff dough is formed. If this is washed in water the inorganic salts will dissolve, the starch will wash out to form a suspension, and the proteins will combine with some of the water to form an elastic substance known as gluten. Gluten is the substance that gives the framework to bread, rolls, biscuits, muffins, and cakes.

Milk is a mixture containing about 87 per cent of water, lactose and salts in true solution, protein in colloidal solution, and fat in emulsion form. If the milk is homogenized, that is, is forced by high pressure through small holes, the fat globules are broken, become coated with casein, and the very small fat globules formed will remain distributed throughout the mixture; otherwise the fat rises to the top of the mixture to form the cream layer. When milk is heated, some of the protein and calcium compounds may separate from it; a "skin" forms on the surface of the milk when it is scalded and a precipitate clings to the bottom and sides of the pan. Butter is essentially a mixture of water, salt, and fat. If it is heated slowly, the fat will soften, melt, and separate from the salt and water. The presence of the water and the salt prevents cooked foods from browning as readily when heated in butter as when they are heated in lard, hydrogenated fat, corn oil, or cottonseed oil. These fats are not pure compounds but mixtures of glyceryl esters of high-molecular-weight acids called fatty acids.

As is characteristic of mixtures of solids, the melting point of a solid fat is never sharp nor constant. Consequently, when a liquid fat is chilled in the refrigerator, it often happens that only part of the mixture solidifies. In hot weather the comparatively low melting point of butter and lard may be of great concern to the housewife.

But frequently the decomposition temperature of a fat is of more interest to the cook than the melting point. When fat is used for deep-fat frying or for sautéing, temperatures higher than 390°F. may be reached. If the fat decomposes, appreciable quantities of propenal, commonly known as acrolein, are produced. Few things are more distressing in the kitchen than this acrid-smelling, tear-producing compound and the smoky blue haze that accompanies it. Butter fat is never used for deep fat frying because of its relatively low decomposition temperature. Every effort is made by manufacturers of the other fats, however, to make products that do not decompose readily.

The large proportion of fat in pie crust, together with the high oven temperature (450°F.) recommended for its cooking, frequently spell disaster for the cook. A burned pie crust or one so brown that the decomposed fat imparts a bitter flavor is no delicacy. If a low baking temperature is used, however, the fat melts before the flour mixture sets and a mealy crust rather than a flaky one is produced. The wise cook, therefore, has learned to use the high temperature and to watch the pie.

The temperature at which meat is cooked, however, is a different story. Not so many years ago very high temperatures were recommended for the broiling of steaks and chops and for the searing of roasts. As a result, not only was the fat frequently burned but it often caught on fire in the broiler. The characteristic steak of that period had blackened edges immediately next to which was an area of hard, gray, dry meat; the innermost portion might be either rare or well done, as preference dictated. Fortunately, lower temperatures for broiling and for roasting meat are now recommended. As a result the fat is not burned and the meat is more evenly cooked and more juicy.

Meat and egg protein are complex materials that are colloidal in nature. When heated to a certain rather low temperature these colloidal materials will jel, and in so doing they take up and retain definite quantities of liquid. The material, however, is very sensitive to heat, and if, after it has jelled, it is heated very hot or very long the protein will shrink and the liquid will be expelled. This phenomenon is known as syneresis.

The result will be dry meat with the flavorsome juice in the pan. For this reason any kind of meat except pork is roasted at 325°F. or lower. If one is fortunate enough to have a meat thermometer, rare meat is cooked to an internal temperature of from 135° to 140°F., medium rare from 155° to 160°F., and well-done meat to 170°F. Pork is roasted at 350°F. and cooked until it is well done to insure killing of the organism responsible for trichinosis.

The result of cooking custard at a high temperature is either a "weepy" baked custard composed of a somewhat tough flavorless gel surrounded by a sweet watery juice, or else a curdled stirred custard that feels rough and lumpy to the tongue. After the liquid has separated, that is, after syneresis has taken place, there is little one can do to remedy matters. Beating the soft custard with a rotary beater will help somewhat but not even this much aid can be given the baked product. To keep the temperature of custards low, baked custard is cooked in a dish set in hot water, whereas stirred custards are cooked over hot water on top of the stove.

Baked custard, cornstarch pudding, puddings thickened with flour, gelatin, and fruit jellies are called gels. Each of these foods contains a lyophilic or liquid-loving colloidal material such as egg, cornstarch, flour, gelatin, or pectin. The conditions that favor the formation of gels vary with the different colloidal substances present. Gel formation takes place in a baked custard, for example, when the egg mixture is heated, but with the other products mentioned gel formation occurs after the food has cooled. The kind and quantity of acid present has an influence. The jellying power is also affected by the concentration of sugar.

In fruit jelly the amount of sugar that can be used to make a good jelly depends upon the amount of pectin present. A simple instrument called a jelmeter has been devised by means of which the pectin content of a fruit juice can be estimated. This is a glass tube drawn out to a capillary at one end. To make a test, the jelmeter is filled with cooled, strained fruit juice that has been extracted for jelly making. The juice is then allowed to flow through the jelmeter for exactly one minute. The rate at which a juice will flow depends upon its viscosity and the viscosity depends upon the pectin content. If much pectin is present the level of the juice remaining in the jelmeter will be high after one minute of flow and low if there is little pectin.

The amount of sugar that should be used to make a good jelly is indicated on the jelmeter; too little sugar gives a tough jelly and too much a jelly that will not hold its shape. If fruit contains too little pectin to make a good jelly, apples may be added, since they have a considerable quantity of pectin. Commercial pectins on the market are also satisfactory for use with fruit juices that do not have enough pectin.

The acidity or hydrogen-ion concentration of the fruit juice also plays an important part in the making of jelly. If the concentration of hydrogen ions in a solution is high, the solution is said to be acidic. If the concentration of hydroxyl ions is high, the solution is said to be alkaline. If the concentration of hydrogen ions and hydroxyl ions in any solution is the same, the solution is said to be neutral and the pH is 7. The pH is less than 7 if there are more hydrogen ions than hydroxyl ions but more than 7 if there is an excess of hydroxyl ions. A good jelly may be made if the pH of the juice is between 3.1 and 3.4. A juice with high acidity, or as the scientists would say with high hydrogen-ion concentration (low pH), may give a jelly that "weeps," that is, shows syneresis. This happens frequently to cranberry jelly. A juice with a low hydrogen-ion concentration (high pH), will give a jelly that cannot hold its shape. Unfortunately, there is as yet no simple way for the housewife to measure this, and she must trust to experience to tell her whether a fruit juice is sufficiently acid or whether acid from other fruit should be added.

Foams and emulsions are also colloidal systems that are important in cooking. Egg-white foam is familiar to all. When egg white is beaten, bubbles of air become surrounded by a film of protein and water which is capable of being greatly stretched. Anything that will increase the ability of a liquid to spread will lower its surface tension and increase its ability to foam. The protein of the egg white increases the ease with which the surface of the water may be broken. Thus egg white foams more readily than water alone. Since egg whites at room temperature have a lower surface tension than when chilled, they whip more quickly and give a better volume. As eggs are whipped longer the number of air bubbles surrounded by egg-protein films increases and they become progressively smaller. The runny, easily collapsible foam that forms at first changes to a shiny, somewhat stiffer, whiter, and more stable one. In this form the foam can be easily folded into thick sauces to make souffles, or into slightly stiffened gelatin mixtures to make snow puddings or chiffon pie fillings. If the beating is continued until the foam becomes dull, however, the egg-white protein coagulates and not only ceases to stretch but also breaks, and liquid separates from it. Such a collapsed foam cannot be folded satisfactorily into thickened mixtures and they will not have the added volume that a properly beaten foam would give.

In the making of meringues or angel food it is desirable to make a stable foam that will not collapse on standing. Both sugar and cream of tartar help to stabilize egg-white foam. Fat, however, causes foams to collapse. For this reason a good egg-white foam will not result if any of the fat-containing yolk is present. This is also one of the reasons why angel-food pans are not greased.

The volume occupied by a gas increases as the temperature increases. This is of great importance in baking. Air, steam, and carbon dioxide are leavening gases which make baked products rise. In the preparation of angel food, soft meringues for pies, hard meringues, or kisses, air is incorporated when the egg white and sugar are beaten together. The egg-white protein film stretches and surrounds many small bubbles of air.

During baking, heat causes the air to expand; the product is said to rise. When the beaten egg white is heated further it coagulates and becomes firm and expansion stops. On removal from the oven, even though the air contracts, the egg-white structure is firm enough to hold its shape at the expanded volume. Angel food is cooled in the pan, and if the pan is not greased the cake will cling to the sides and its fragile framework will not collapse as the volume of the gas contracts on cooling. Although the sides of the pan in which butter cake is baked may not be greased either, there is usually enough fat in the cake to cause it to shrink away from the sides of the pan during cooling.

Steam plays an important part in causing baked products such as popovers and cream puffs to rise. Carbon dioxide is, however, the most common gas that leavens food products. Cakes, muffins, baking powder biscuits, steamed breads and puddings, rolls, and bread are all leavened by this gas although it may be obtained from different sources.

Carbon dioxide may be obtained from yeast or from the reaction between baking soda and an acid. That a salt may react with an acid to form a new salt and a new acid, if the new acid is more volatile than the original one, is a familiar principle. Thus a carbonate in the presence of an acid will give a new salt and carbonic acid (equation 1).

$$\underset{\text{baking soda}}{NaHCO_3} + \underset{\text{acid}}{H^+} \rightarrow \underset{\text{carbon dioxide}}{CO_2\uparrow} + \underset{\text{water}}{H_2O} + \underset{\text{sodium ion (part of a sodium salt)}}{Na^+} \qquad (1)$$

Since carbonic acid is very unstable, it decomposes quickly to form carbon dioxide and water. The carbonate used in home cooking is always sodium bicarbonate, familiarly known as baking soda and known to our grandmothers as saleratus. The source of all or part of the acid may be acid buttermilk, soured unpasteurized milk, vinegar, fruit juice, dried fruits, molasses, brown sugar, or chocolate or it may be one or more of the ingredients of baking powder, such as cream of tartar, tartaric acid, monocalcium phosphate, or sodium aluminum sulfate, sometimes called alum.

Baking powder is a mixture of baking soda, one or more of the acid ingredients just mentioned, and starch. Three types of baking powder are available to the housewife: tartrate, phosphate, and alum phosphate (S.A.S.). The type is named from the acid ingredient. All are required by law to give a minimum of 12 per cent by weight of carbon dioxide. The starch serves two purposes: it acts as a filler to keep the yield of carbon dioxide near the legal requirement and it absorbs the moisture that otherwise would permit the baking soda and the acid ingredient to react in the can.

Baking soda is, however, not the only source of the carbon dioxide used in cooking. During growth, yeast supplies it for bread and rolls, the essential ingredients of which are flour, liquid, salt, and yeast. Fat, eggs, and sugar are frequently added.

Flour contains both starch and the enzyme, diastase, which hastens the hydrolysis of some of the starch to the sugar, maltose (equation 2).

$$\underset{\text{starch}}{2(C_6H_{10}O_5)} + \underset{\text{water}}{xH_2O} \xrightarrow[\text{from flour}]{\text{diastase}} \underset{\text{maltose}}{xC_{12}H_{22}O_{11}} \qquad (2)$$

During any hydrolysis water is broken up and enters into the formation of one or more new substances. Other hydrolytic reactions occur during the making of rolls. Some of the maltose formed is hydrolyzed to the simple sugar, glucose, in the presence of the enzyme, maltase (equation 3). The enzymes, maltase and sucrase (invertase), are both found in yeast.

$$\underset{\text{maltose}}{C_{12}H_{22}O_{11}} + \underset{\text{water}}{H_2O} \xrightarrow[\text{from yeast}]{\text{maltase}} \underset{\text{glucose}}{2C_6H_{12}O_6} \qquad (3)$$

This simple sugar acts as the immediate food for the yeast. If cane or beet sugar, known to the chemist as sucrose, is available, some of it is hydrolyzed in the presence of the enzyme, sucrase, to give two simple sugars (equation 4).

$$\underset{\text{sucrose}}{C_{12}H_{22}O_{11}} + \underset{\text{water}}{H_2O} \xrightarrow[\text{from yeast}]{\text{sucrase}} \underset{\text{glucose}}{C_6H_{12}O_6} + \underset{\text{fructose}}{C_6H_{12}O_6} \qquad (4)$$

In the presence of a third yeast enzyme, zymase, fermentation of glucose with the formation of carbon dioxide and alcohol takes place (equation 5).

$$\underset{\text{glucose}}{C_6H_{12}O_6} \xrightarrow[\text{from yeast}]{\text{zymase}} \underset{\text{carbon dioxide}}{2CO_2} + \underset{\text{ethyl alcohol}}{2C_2H_5OH} \qquad (5)$$

The rate at which carbon dioxide is formed is an indication of the rate at which the yeast plant is growing. The rate of growth is controlled by the ingredients in the dough, its temperature, and the presence of air. As more and more carbon dioxide is formed (equation 5), the dough rises higher and higher, and if the temperature is well controlled and proper ingredients are selected only the faint odor of alcoholic fermentation is noticeable. If conditions have not been controlled, however, foreign fermentation may take place, producing an odor often described as "yeasty." This odor is caused largely by aldehydes, acids, or alcohols other than ethyl alcohol. Whereas during rising it is desirable to have the enzymes active, if the best flavor is to be obtained their action should be stopped as quickly as possible after the dough has been put in the oven. For this reason bread and rolls are usually baked at about 400°F.

Bread making is not the only food process that depends upon microörganisms to bring about the necessary chemical changes. When wine is made from fruit, yeasts are necessary for the alcoholic fermentation; the making of cider vinegar requires acetic acid bacteria to help change ethyl alcohol to acetic acid; and the production of sauerkraut requires that lactic acid bacteria be present before the sugar, lactose, is converted into lactic acid.

Several microörganisms—yeasts, molds, and bacteria—can cause chemical changes that result in food spoilage. Familiar examples are the fermentation of fresh fruit, the molding of such products as bread, bacon, and smoked fish, and the decomposition of many improperly stored fresh foods. Microörganisms are particularly troublesome in canning, and every effort is made to avoid their presence and to destroy them by heating. Good food is selected, hermetically sealed in suitable containers, and heated for a certain time at 212°F. for fruits and 240° or 250°F. for vegetables and meat. If glass jars are used they are sometimes sealed *after* heating. Yeasts or molds, which thrive in the presence of acids, sugar, and moisture, usually cause the spoilage of improperly packed or processed acid foods such as tomatoes and fruits.

The old-fashioned method of canning tomatoes and fruits called for cooking them in an open kettle, transferring to hot jars, sealing, and storing. Much food spoiled because yeasts and molds from the air contaminated the food when it was transferred to the jars. The temperature of the fruit was apparently not high enough to destroy the organisms in spite of the fact that they can be destroyed at quite low temperatures. It sometimes happens that only alcoholic fermentation occurs in sweetened fruit, in which case it may be eaten. Usually, however, there is a sour or cheese-like odor and the product is not fit to eat.

The modern method of canning tomatoes and fruit is to heat them in a boiling water bath after they are packed in the jars, and then to seal them. There is then no danger that they will be contaminated by microorganisms from the air. Heating jelly in the final container is neither practicable nor necessary because it contains more sugar and reaches a higher temperature than does canned fruit. At sea level the jelly is at approximately 219°F. when cooking is finished and it is ready to be put into the glasses. If the transfer is made quickly and hot paraffin is poured immediately on the surface, there is little danger that the microörganisms can survive to cause spoilage. In contrast to yeasts and molds, bacteria do not tend to grow in an acid medium so they do not offer a problem in the canning of fruit.

Bacteria thrive in "non-acid" foods (pH 4.7 to 6.8) such as vegetables and meats; yeasts and molds do not. The hydrogen-ion concentration is so low in the non-acid foods, that the term non-acid is applied even though the pH is lower than 7. Bacteria are the chief trouble makers in canning because they may exist in heat-resistant forms called endospores. If the spores are not destroyed they develop when the canned food is stored and the food spoils. Since the spore form of the bacteria is often not destroyed at 212°F. even after six hours' heating, it is desirable to can vegetables and meats under pressure in order to obtain temperatures of from 240° to 250°F.

Some bacteria during their growth produce extremely poisonous substances called toxins. One of the most dangerous of the toxin-producing organisms is *Clostridium botulinum*, which is found in the soil. The bacterium produces heat-resistant endospores which are harmless themselves, but which, if not destroyed during the heating period, develop in the cans during storage, and produce the poison. The toxin causes botulism, a disease usually fatal even though only one taste of contaminated food is taken. A gas may be formed and the food may have a dark or mushy appearance and a cheesy or putrid odor. Any food showing even slight signs of such spoilage should be discarded without tasting. Unfortunately, visible signs of spoilage are not always evident when the fatal toxin is present. The toxin is rare but has been found in home-canned meats, in soup mixtures, and in such non-acid vegetables as asparagus, corn, greens, peas, and snap beans which had been canned at 212°F. Although acid foods such as fruit products and tomatoes are generally not subject to this type of spoilage because the organism seldom develops in such an acid medium, in 1940 a fatal case of botulism from home-canned tomatoes occurred. The tomatoes had been canned at an unusually low temperature. To be sure that the spores are destroyed, meat and non-acid vegetables must be canned in a pressure cooker, for this is the only method whereby a temperature high enough to kill the spores can be reached.

While the most important criterion of quality in canned food is freedom from microörganisms, the most important consideration in cooking most food, is the conservation of its food value as much as possible. This is of particular importance in the boiling of fresh vegetables, because of the danger of dissolving valuable food in the water. Time is required for a solid to go into solution; the length of time is usually shortened if the exposed solid surface is large, if the amount of liquid is large as compared to the amount of solid, if the liquid is hot rather than cold, and if the mixture is agitated rather than permitted to stand undisturbed. Consideration of these factors will help materially in keeping the greatest possible food value in vegetables during boiling.

In the large quantity of water distributed throughout the fibrous cellulose structure of fresh vegetables are dissolved small quantities of sugar, salts (sometimes referred to as mineral matter or ash), and water-soluble vitamins such as ascorbic acid, thiamin, riboflavin, and nicotinic acid. Occasionally other food material is present. When the vegetables are eaten raw all of these food materials are consumed, but unless reasonable care is taken much of the valuable material may be lost in the cooking water. If the vegetables are baked or steamed or if they are cooked with their skins on, very little or no soluble material is removed. If, however, as so frequently happens, the vegetables are pared and then cooked in boiling water, relatively large quantities of soluble material may be lost, especially if the quantity of water used for cooking is large, the length of time of cooking is long, and the cooking water is discarded. A good practice to follow in the cooking of vegetables, therefore, is to place them in as small a

quantity of rapidly boiling water as is practical, to cook them just long enough to make the vegetable tender (not soft), and to serve the cooking liquid with the vegetable whenever possible. This is the way fruit is often served but for some unaccountable reason the water in which pared vegetables have been cooked is frequently thrown away.

Aside from the mineral matter and the water-soluble vitamins that may be lost by dissolving in the cooking water, some of the ascorbic acid (vitamin C) is lost through oxidation. An oxidizing enzyme occurs in the vegetable itself, which, in the presence of air, destroys ascorbic acid. If the air has been boiled out of the water and if the water is rapidly boiling before the vegetable is added the enzyme is destroyed quickly and the destruction of ascorbic acid is reduced to a minimum. To protect ascorbic acid as well as thiamin the addition of alkali to the cooking water must be avoided. Although a little soda will intensify the green color of vegetables, it will also cause the destruction of much of the ascorbic acid and thiamin present, make the texture of the vegetable soft and even slimy, and destroy the natural flavor. Its use, therefore, cannot be justified.

Although in cooking vegetables it is desirable to avoid dissolving materials in water, in candy making it is necessary that substances be dissolved. The simplest candy consists of sugar, liquid, and some flavoring; whether such candy is creamy or crystalline, runny or crumbly, or soft or brittle depends upon how long it is cooked and how it is treated during and after cooking. To help keep it soft and creamy or to make it chewy, ingredients other than the essential ones are used. For variety such things as nuts, fruits, chocolate, coconut, or cereal may be added.

In making a creamy candy like fondant, water, sugar, and a little corn sirup or cream of tartar are heated together to form a solution. As the solution is boiled in an uncovered pan, water evaporates, the sirup becomes more concentrated, and the boiling point rises. When the temperature of the sirup is about 26°F. higher than the boiling point of water, cooking is stopped and the sirup is allowed to cool, particular care being taken to leave it undisturbed and to avoid letting sugar crystals fall into it.

When the candy has finished cooking, the hot sirup is still an unsaturated solution. As it cools it becomes saturated, and before kneading or beating the sirup becomes supersaturated if no sugar crystals have been dropped in and if the material has not been unduly disturbed. If the sirup is beaten while it is hot, crystallization begins almost immediately, a greater number of nuclear crystals separate at one time than can be beaten away from one another, and the fondant becomes granular. At the other extreme, if the sirup is allowed to become cold before it is beaten, the mixture becomes very shiny and stiff and it is difficult for crystals to separate out; sometimes they do not form at all. If, however, the sirup is cooled only to about body temperature and is then beaten, the crystals that form can be whisked away quickly so that they cannot grow on one another; then the fondant will be smooth and creamy. During the time when crystals are separating most quickly from a candy, the entire mixture may be observed to soften. This is because of the heat given off (heat of crystallization) when crystals are formed.

If corn sirup, glycerin, or cream of tartar is added before cooking, the fondant is more creamy than if sugar and liquid only are cooked together. The addition of any of these ingredients causes an increase in the viscosity of the sirup just as does the cooling of the sirup. It is more difficult for crystals to separate from a viscous solution than from a non-viscous one. Thus it is possible to beat a viscous mixture fast enough to obtain small crystals. The glycerin and the corn sirup are viscous themselves and so increase the viscosity of the sirup. The cream of tartar or any other acid substance converts a small amount of the sugar, sucrose, into the simpler sugars, glucose and fructose (equation 6).

$$\underset{\text{sucrose}}{C_{12}H_{22}O_{11}} + \underset{\text{water}}{H_2O} \xrightarrow{\text{hydrogen ion}} \underbrace{\underset{\text{glucose}}{C_6H_{12}O_6} + \underset{\text{fructose}}{C_6H_{12}O_6}}_{\text{invert sugar}} \qquad (6)$$

This particular hydrolysis of sucrose is also called inversion and the mixture of glucose and fructose is referred to as invert sugar. It will be remembered that the enzyme, sucrase (or invertase), can also speed up this reaction. Glucose and fructose do not crystallize as readily as does sucrose and the simple sugars also prevent sucrose from crystallizing as easily as it otherwise would. If a very large amount of acid or viscous material is added, as in the making of caramels, crystals may never be able to separate from the solution.

For a similar reason ice crystals may never separate from some of the ice creams that are made in mechanical refrigerators. The recipes frequently call for comparatively large quantities of colloidal substances such as starch, gelatin, chocolate, cream, evaporated milk, or condensed milk. Although the colloidal substances do not affect the freezing point, one of two things may happen: either ice crystals never manage to separate from so viscous a medium or a few come out and, because of the excellent conditions for growth, become very large. Neither product is very satisfactory as an ice cream. If the quantity of colloidal material is small a very coarsely crystalline product may be formed because the mixture is not continuously stirred as is done in the old-fashioned freezer. A refrigerator ice cream that may have a satisfactory texture at a given time may be coarsely crystalline several hours later. It is therefore advisable to use it promptly.

In the making of churned ices, sherbets, or ice creams, the same principles apply as in the making of fondant. In the case of fondant, however, a solid, sugar, is crystallized from its solution whereas in the making of frozen desserts the solid form of a compound, ice, is being formed from the liquid state, water. If only fruit juice, water, and sugar are used, the product is called an ice. If substances of a colloidal nature such

as gelatin, milk, or egg white are added, the product is called a sherbet. Because the colloidal material present in such mixtures increases the viscosity of the mixture, ice crystals separate quite slowly and therefore can be whisked away from one another during churning. The result is that a sherbet usually has smaller crystals than does an ice, has more body, and melts less quickly. As the quantity of colloidal material is increased, as in ice creams, a smoother, richer, and more substantial food is produced.

Thus, the cook is a chemist. It matters not whether she is making a first course of cream of tomato soup, a main course of meat and vegetables, a gelatin salad with mayonnaise dressing, a dessert of custard, ice cream, or snow pudding, or creamy mints and the coffee to top off the meal. A good chemist *should* be a good cook!

# LETTERS

### Must Elementary Chemistry Be Semantically Confusing?

*To the Editor:*

For the past six years I have been attempting each year to teach certain elementary chemical principles to about seventy graduates of college chemistry courses (medical students) from all over the country. As medical students they are supposed to learn the principles behind the calculation of hydrogen-ion concentration and other applications of the mass law, and one of my jobs is to see how much of the foundations of chemical principles they have left from their college studies. I am convinced that the following almost universal defect in their thinking is an important source of continued confusion, and that it represents a fairly widespread lack of clarity in elementary textbooks of chemistry and in college chemistry teaching.

Very few of these students can give a clear definition of the term "molecular weight." Most of them can recite a logical sentence about the "gram atomic weight" but it is apparent that this term, along with "gram molecular weight," is the source of an initial and continuing inability to see clearly the method of using the molecular weight in any but the simplest calculations. In my opinion the term "molecular weight" can be defined in only one way, and if the terms "gram atomic weight" and "gram molecular weight" are to be used in elementary chemistry courses their introduction should be deferred until the student is safely beyond the risk of permanent confusion.

The molecular weight of any substance is the number of grams per mol (grams/mols). This is the only definition which can be used in calculations involving grams, mols, molarity, specific gravity, and per cent by weight if the centimeter–gram–second system is used. The "mol" must be defined first, of course. A mol of any substance is that amount which contains the arbitrarily chosen standard number (Avogadro's number) of molecules. The definition of an "equivalent" is analogous. By the statement that the above definition of "molecular weight" is the only possible definition I mean just that, because it is the only definition which will work.

Clarity of thought on the subject of dimensions is not, of course, indispensable to the carrying out of good chemical experiments. It is, however, a tremendous advantage in teaching. Its absence necessitates something almost analogous to a complete psychoanalysis of any student to whom one is attempting to explain "principles" of chemistry. By far the greater part of such analyses I carry out on students lead directly back to the mental trauma inflicted by such terms as "gram atomic weight" and "gram molecular weight."

Besides, if teachers of elementary chemistry purport to be teaching "science" they should either be pretty clear about definitions and dimensions or else, God forbid, hand them over to the Department of Philosophy.

THOMAS B. COOLIDGE

DUKE UNIVERSITY SCHOOL OF MEDICINE
DURHAM, NORTH CAROLINA

### One!

*To the Editor:*

Having just read the "Editor's Outlook" in the January issue of the JOURNAL OF CHEMICAL EDUCATION, and having just prior to that, believe it or not, finished the article by H. A. Spoehr on carbohydrate formation, I could not resist the temptation to sit down and let you know that one teacher read the article.

I concur heartily with you in every word you say regarding the secondary-school teacher. Not being too familiar with the college instructor's problems, I'll keep silent on them. Let me say, however, that it is no joke to keep up. Our first job is to teach—anything, perhaps a Latin course, a history, or a stray course in English. Secondly, we have been expected to teach with one main objective—the College Board examinations. And then, if we have time we teach some chemistry. Of course, you must remember an important function in a small preparatory school is athletic coaching. That leaves your evenings free to correct papers and prepare advance lessons. So far, I find Sunday mornings after church my one opportunity for professional advancement, and the JOURNAL is like an oasis in a desert. . . .

ROBERT W. NEATHERY, JR.

WOOSTER SCHOOL
DANBURY, CONNECTICUT

**Two!**

*To the Editor:*

As a member of the large group of high-school teachers that were the target of your editorial in the January issue of the JOURNAL OF CHEMICAL EDUCATION, I want to say Amen, to your insinuations and suggestions.

This is my fifth year of teaching, just chemistry, otherwise I don't think I'd still be in this field. I am still shocked by the juvenile questions some of my colleagues ask of men in their field at state conventions and professional meetings. I'd be ashamed of my pupils if they asked such stuff and have long been wondering why this is true.

Your editorial strikes at some of the basic reasons but I believe there are others, not that they justify us as teachers but they do exist.

1. Chemistry teachers' interests are divided, not only as to teaching and chemistry but to many other fields.

2. Professional journals and societies are *too expensive* for high-school teachers who make $1000 to $1500 a year, in terms of the services they render.

3. Last, but most important in my mind, many of us have been content to base our work on what we had in Chem 108 or 305. We've either *never been challenged* or *we've missed the boat*, so that we're content to use our fifteen-year-old texts and older ideas and not meet the demands of many of our students. Our background has been too limited. I have practice students from the local teachers college and am made more conscious with every term that I was fortunate in having more when I began my chemistry teachings, than they have. How they get along I can only guess. Much of what their pupils will get will be in spite of the teacher and not because of him. . . .

W. G. KESSEL

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TERRE HAUTE, INDIANA

P.S. I read the article "Origin and Transformation of Carbohydrates in Plants."

# What's Been Going On

EXTRUDED plastic threads are being used to make window screens which never need painting. They are said to cost about the same as copper screens.

The following are on the list of strategic materials—for other reasons than their strange names: tragacanth, dragon's blood, abaca, kapok, karaya, sisal, henequen, damur, kauri, vetivert, ylangylang.

Sugar-coated steel! Absolutely dry, pure corn sugar is blown on the inner surface of the ingot molds. When molten steel is poured in the molds splashed metal is prevented from solidifying on the sides of the mold, thereby producing a better surface on the steel. The sugar coating on the steel disappears in later processing, of course.

Alloys obtained by addition of cadmium to copper are used in making trolley wire. They are said to have better electrical conductivity than the older, standard copper-tin alloys used for the same purpose.

As an example of the work of microchemistry it was discovered in the Westinghouse Research Laboratories that tarnish film spots interfered with the operation of vacuum tube filaments. Analysis showed that bits of silica, or glass, from the tubes' bulbs had deposited on the filaments. This analysis called for the distillation of extra pure water, because the ordinary distilled water used in the laboratory had been kept in glass bottles and had dissolved enough silica to confuse the measurements of the silica in the film sample. This special water had to be stored in platinum bottles.

From the same laboratories comes the report of a new material, "Prestite," which has released badly needed defense materials and provided a substitute which in a number of instances out performs the materials it displaces. Although Prestite is properly termed a new plastic because it is formed accurately to intricate shapes, it is actually a porcelain because it is made from exactly the same ingredients as that product and is fired in the same kiln with it. Mechanically, the plastic is as strong in compressions as wet process porcelain. It retains its mechanical strength without deformation or warpage at temperatures that would completely destroy phenolic plastics. Electrically, the material is the equivalent of wet process porcelain. It has the same dielectric strength, is completely impervious to moisture, may be subjected to repetitive flashover without surface charring, and otherwise behaves like the highest grade of electrical porcelain. It has also replaced aluminum for use in water-cooler reservoirs.

In recent months Americans have had the opportunity to see many of the finished weapons produced for national defense. The drab paints used in World War I appear bright and shiny alongside the lusterless enamels being used today. These enamels dry without gloss and have very poor photographic property. A lusterless blue enamel which is used over the olive drab for lettering tanks, trucks, and other equipment, shows less contrast than did the black enamel formerly used for lettering.

Green cotton, said to yield 30 times as much wax as the ordinary white varieties, gives promise of becoming an important source of wax for polishes. Manufacturers of furniture polishes, floor polishes, auto polishes, and similar protective finishes requiring a wax with a high melting point would benefit chiefly from the use of the new material, especially in case of an acute shortage of wax from the usual sources. Southern cotton farmers would find an always welcome new market.

Because of metal shortages substitute materials are being earnestly sought by manufacturers of many metal articles. As an example of successful substitutions, experiments with glass kick plates for doors have been carried on. Kick plates made of 1/4-inch Herculite polished plate glass have been found satisfactory.

WE HAVE been told that the spectrograph is such a sensitive analytical instrument that it will detect lead in the blood of a person who has slept in a room which has just been painted. Can this be the reason why we wake up with such a *heavy* feeling sometimes? Do we need a spectrograph to tell us why?

# Out of the Editor's Basket

IN CONNECTION with the chemistry course in the Engineering Defense Training program at Pennsylvania State College, described elsewhere in this number, a novel means of giving lecture demonstrations was made use of. For several years the Franklin Institute of Philadelphia has had equipment to present popular lecture demonstrations to high schools and general audiences. This unit was rented and, with slight changes, fitted the needs of this course very well. The equipment consisted of a GMC truck fully loaded with some eighteen boxes of chemical apparatus, portable lecture tables, lights, charts, etc. The careful packing of equipment was one of the most unique features of the show. By combining the classes from adjacent centers at some performances it was possible to reach all the 3000 students throughout the state. Despite some six thousand miles of travel nothing was broken in transport. The demonstration took about an hour and a half and was given once or twice a day for eight weeks. It aimed to review and illustrate a large number of fundamental principles, although it could not cover all the subjects of the course.

The plan did not pretend to display chemistry like a traveling groceteria. Nor did it pretend that it was a substitute for the real thing—a complete college course. But it was a satisfactory complement to a hastily arranged program for defense training courses in chemistry. The men responsible for it were R. D. Billinger, of Lehigh University; A. D. Rose and Lester Kieft, of Pennsylvania State College and N. H. Smith of the Franklin Institute.

A LECTURE DEMONSTRATION ON WHEELS

● P. M. Dassel and J. M. Buthod, of Evansville College, Evansville, Illinois, describe a simple method for obtaining a steady sodium flame. It consists of a small roll of asbestos cloth, dipping into a saturated solution of NaCl and then bent horizontally to reach into the base of the flame of a Bunsen burner. Such a "wick" supplies sodium to the flame. They suggest an asbestos mitten, such as is used to handle beaker tongs.

● G. C. Brous and L. B. Poland, of Hofstra College, recently made a survey of the summer school offerings in chemistry at forty-three of the smaller eastern colleges and universities, in order to see what solutions are offered to the problem of crowding a full semester's or year's course into a short session.

At only five or six institutions was the session longer than six weeks and in only one case as long as ten. Out of 18 offering general inorganic, six gave "double" courses carrying six or eight semester hours credit. These involved 60 to 108 total hours of lecture and recitation and 105 to 144 total hours of laboratory. The rest were courses of two to four semester hours credit, 30 to 48 total hours of lecture and recitation and 18 to 60 hours of laboratory. Five out of twelve offered double courses in organic, with 60 to 108 total hours of lecture and recitation and (with one exception) from 108 to 144 hours of laboratory. Courses in analytical, both qualitative and quantitative, were more uniform, only one double course in quantitative being listed. All the others included 30 to 45 hours of lecture and recitation and 45 to 90 hours of laboratory.

● E. C. Young, of Berwyn, Illinois, makes a plea for a thoughtful and coöperative attitude on the part of all chemistry teachers in the present war emergency. He suggests that care be taken in the matter of purchasing and "hoarding" chemicals and supplies. High schools might well turn over supplies of such things as acid-washed asbestos and magnesium turnings to college or industrial laboratories, where they can be put to more important use. Articles like the following, which are scarce and in demand, should not be hoarded, but conserved and purchased judiciously: acetone, alcohol, formaldehyde, phenol, toluene, thiocyanates, molybdates, nitrates, phosphates, ammonia, and potassium salts. It should not be stipulated that "all chemicals must meet A. C. S. specifications."

● E. E. Johnson, of Creighton University, whose hobby is microchemistry, describes a portable microchemistry set, a small suitcase, six by twelve by fifteen inches, containing the following: 60 vials of reagents in Microchemistry Kemkit #151; "Handbook of Chemical Microscopy," Volume 2, by Chamot and Mason; a 425 power microscope; a small alcohol lamp and

bottle for alcohol; a homemade substage microscope lamp; a centrifuge made from a small hand-driven grindstone; a wash bottle; a jar for waste water; a screw-cap jar containing ammonia and acetic, hydrochloric, nitric, and sulfuric acids; a towel.

● If and when blackouts become common we will doubtless see the appearance of clothing dyed with

*Courtesy Calco Chemical Division, American Cyanamid Company*

FLUORESCENT-DYED CLOTHING
In visible light In ultra-violet light

fluorescent dyes and the use of ultraviolet light. Such dyes are already available in a number of colors: violet, blue, green, yellow, orange, brown, and red. In certain kinds of blacked-out plants workers in such clothing might be able to continue their operations. Traffic control would be possible with ultraviolet lamps in traffic lights and headlights of vehicles. The effect of such clothing is shown in the illustrations.

From the Westinghouse Electric Company comes the information that while the London blackout is accomplished by permanent shields and low wattage lamps which must remain throughout the war, the American variety will be controlled from power stations. It will only be temporary.

By the use of camouflage lights, engineers will be able to build decoy airfields, bridges, and other faked military objectives in deserted areas. The illusion of an important bridge span might easily be created by stringing rows of lights across a river in some isolated section. A well-lighted empty meadow several miles from a city could pose as an airfield if other parts of the city itself were not completely darkened.

● Theodore C. Sargent, of Swampscott, Massachusetts, speaking before the N. E. A. Department of Science Instruction at its meeting in Boston, directed attention to the need of re-examining methods and curriculum used in teaching high-school chemistry. To meet the needs of present society, he offered these four suggestions:

(1) Recognize the importance of reading by increasing the student's ability to read rapidly, appreciatively, and extensively all types of readable material—books, pamphlets, magazines, as well as trade announcements and commercial literature with direct relationship to the subject.

(2) Recognize the importance of experience under guidance by devising meaningful experiences that will use laboratory equipment realistically.

(3) Recognize the importance of consumer-oriented teaching by placing more than ordinary emphasis upon the need for better use of consumer goods through chemistry.

(4) Recognize the importance of professional organizations and group activity to promote group interests in investigation and research.

● Those interested in visual education should know of Pamphlet No. 80, "Sources of Visual Aids for Instructional Use in Schools," issued by the U. S. Office of Education, Washington, D. C.

● Pamphlet No. 22, issued by the same Office, is entitled "Food for Thought: The School's Responsibility in Nutrition Education." High-school chemistry teachers who are anxious to adapt their work to wartime needs should be familiar with this.

● With army officials warning educators to speed up training and to offer more short terminal courses to help the all-out war effort of the nation, the Commission on Junior College Terminal Education has decided to provide from coast to coast this summer three workshops for junior college instructors interested in setting up terminal courses and in studying other problems of terminal education. These workshops will be located on the east coast at Harvard University, in the midwest at the University of Chicago, and on the west coast at the University of California.

● Indeed, we are looking forward hopefully to a production rate of synthetic rubber of 400,000 pounds per year by July, 1943. But it is expected that every bit of this will be required for military use. To us civilians this means that, great as the synthetic rubber program may be, it will not put new tires on our cars. Our present tires will have to last for the duration—perhaps longer—we are being told.

● There are evidences that the manufacturers of good, old-time glue are getting a bit fed up with all this talk about "plastic" airplanes. They claim that glue by any other name may indeed smell sweeter but it is still *glue*, in the accepted sense of the word. They point out,

rightly, that the material of construction is plywood, *glued* together by phenolic or some other type of resin. They claim that it is merely currently fashionable to call everything a plastic that can be remotely connected with that category, but that there is a wide difference between the gluing and the plastic processes. Making an airplane out of plywood stuck together by something which makes the bond stronger than the wood is *gluing*.

On the other hand, the aircraft designers, who ought to know what the argument is all about, claim that the modern plywood materials deserve a distinctive name, for their characteristics are far superior to those in use as late as 1935. The phenolic bonding layer in the new plywoods is not only a plastic itself but is said to impart many of the characteristics of plastics to the wood. One manufacturer, however, recognizes the force of criticism enough to call his product "Wood-plastic."

● A bulletin of the Coleman Electric Company on "Methods and Equipment for the Fluorometric Assay of Vitamins B" should be in the hands of all chemists interested in modern methods of analysis.

● In the October number, 1941, we gave a brief account of the Summer Conference of the New England Association of Chemistry Teachers. The symposium on the teaching of the modern theory of electrolytes, one of the features of the program, has been published in the last REPORT of the NEACT. This can be had, for 25 cents, from the secretary; Sue C. Hamilton, 1109 Boylston Street, Boston, Massachusetts.

## ELECTRON TUBE OSCILLATOR FOR CONDUCTANCE MEASUREMENTS

BOYD E. HUDSON[1] and MARCUS E. HOBBS

*Duke University, Durham, North Carolina*

IN MEASUREMENTS of the conductance of solutions the source of alternating current for the usual apparatus is a direct current fork oscillator, or one of the several electron tube oscillators described in the literature.[2] The circuit described in this paper has been tried and found entirely satisfactory and since the assembly has several features not covered in previous designs, it was felt desirable to report this one.

The use of only one tube, a 117N7GT, simplifies the tube question and decreases the cost of replacements. The single-pole, double-throw toggle switch at $S_1$ in Figure 1 allows a choice as to the intensity of the output. This is a desirable feature since, with dilute solutions, setting of the null point becomes quite difficult unless a variation in output is possible. Most of the essential parts of the circuit may be purchased already assembled in the form of a Mac Oscillator Model A 700,[3] or its equivalent. The total cost of the entire assembly, exclusive of labor, and a few incidental parts is about four dollars and fifty cents.

Figure 1 shows the circuit used. The parts enclosed by the dotted lines are, with the exception of $R_1$, included in the Mac Oscillator. The circuit constants for the chokes in this area are not given as they are a part of the purchased oscillator. The binding posts and connecting resistor on the original oscillator were removed, and the connection to the output transformer was made inside the oscillator case. The terminals of the output transformer were protected by a metal shield as the primary terminals were at high potential. The shunting resistor $R_1$ was enclosed in the oscillator case. Its purpose was to reduce harmonic output.

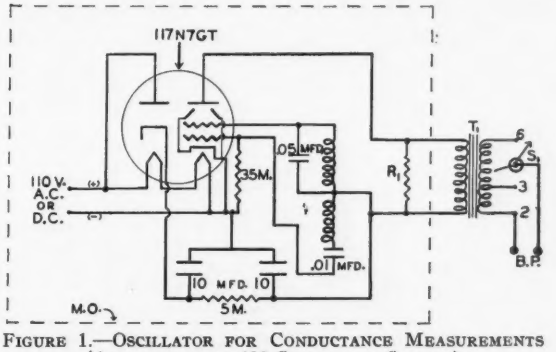


FIGURE 1.—OSCILLATOR FOR CONDUCTANCE MEASUREMENTS (APPROXIMATELY 400 CYCLES PER SECOND)

*M.O.* encloses the parts assembled inside the Mac Oscillator case. $R_1$ is a 100,000-ohm, 1/2-watt resistor. $T_1$ is an Utah P-7984 Universal output transformer. $S_1$ is a single-pole, double-throw toggle switch used to change the intensity of the output. *B.P.* are binding posts for the output connections.

The Mac Oscillator, output transformer, and metal shield carrying the toggle switch and output binding posts were all mounted on a block of wood such that the entire assembly occupied a desk space of approximately four by six inches.

[1] Present address: Standard Oil Development Company, Linden, New Jersey.

[2] (*a*) SAYLOR AND DE BRUNYE, J. CHEM. EDUC., **10**, 703 (1933). (*b*) HULL, *ibid.*, **17**, 329 (1941).

[3] T. R. MacElroy, 100 Brookline Avenue, Boston, Massachusetts. This equipment may also be obtained from most of the wholesale radio houses.

# RECENT BOOKS

THE CHEMISTRY OF PULP AND PAPER MAKING. *Edwin Sutermeister*, S.B. Third Edition. John Wiley and Sons, Inc., New York City, 1941. xii + 529 pp. 62 figs., 13 plates. 15 × 23 cm. $6.50.

As outlined in the preface to the first edition, which is repeated in the third, the aim of the book is to help the young chemist or chemical engineer acquire familiarity with those aspects of paper manufacture which he will need to understand in applying his basic training to the paper industry. Mechanical features are discussed only when they impinge directly upon chemical problems. In order to cover more adequately the rapidly expanding technology of paper manufacture, the author has obtained the assistance of thirteen collaborators, each of whom contributes to one or more of the respective chapters.

The book accomplishes its objective to a commendable degree. The chapter headings provide good coverage of the most important operations and materials involved in paper manufacture, including fairly detailed sections on wood and other fibrous raw materials, followed by several chapters on pulping processes. In spite of the number of authors represented, the style is uniformly good, and the method of treatment of subject matter consistently interesting. The reviewer found surprisingly few misstatements of fact.

The book will probably disappoint research workers of the industry who search in it for a correlation of the multitudinous facts and conflicting statements which have been published in the periodical literature of the last two or three decades. The material presented is itself largely factual in nature, with too little attempt to establish working hypotheses which might ultimately provide a basis for the development of a more sound fundamental background than exists at the present time. Such attempts to theorize would be welcome, even if they did expose the authors to criticism by those who might disagree.

The following chapters, however, deserve mention as being exceptionally well presented and valuable: Chapter I, "Cellulose," by Lewis and Davis; Chapter II, "Fibrous Raw Materials," by Sutermeister; Chapter V, "The Soda Process," by Sutermeister and Greep; Chapter VIII, "Miscellaneous Pulping and Pulp-Treating Processes," by Sutermeister; and Chapter X, "Sizing," by Cobb.

Although the book was copyrighted in 1941, many excellent and fundamental expositions of the past two or three years, which shed light on hitherto perplexing phenomena, are conspicuous by their absence. This presumably is due to the inevitable interval of time which elapses during the editing and publishing of a text involving the work of several contributors.

CHARLES M. KOON

THE INSTITUTE OF PAPER CHEMISTRY
APPLETON, WISCONSIN

PRACTICAL METHODS IN BIOCHEMISTRY. *Frederick C. Koch*, Frank P. Hixon Distinguished Service Professor of Biochemistry, University of Chicago. Third Edition, Revised. The Williams and Wilkins Company, Baltimore, 1941. ix + 314 pp. 18 figs. 15 × 23 cm. $2.25.

In the words of the author, "This laboratory manual is intended to present for medical students the more important qualitative and quantitative aspects of cell constituents, of cell activities and of the composition of blood, secretions and excretions." The book is divided into: Part I. The Chemistry of the Cell Constituents, Part II. The Chemistry of the Digestive Tract, and Part III. Blood and Urine.

Part I includes qualitative and some quantitative work with carbohydrates. After this come experiments with lipids. Proteins are taken up next and a very considerable number of color tests for amino acids are described. Experiments on nucleoproteins and nucleic acids follow. The last pages of Part I are devoted to an explanation of hydrogen-ion concentration and to colorimetric methods of determination.

Part II includes salivary, gastric, and intestinal digestion, and a consideration of the enzymes concerned. On pages 95 and 96 the author employs the obsolete term "erepsin." Bile and its constituents are covered, after which come experiments on blood and hemoglobin. On page 108 the distinction between methemoglobin and oxyhemoglobin is incorrectly stated and on page 109 reduced hematin is confused with hemochromogen. Methods are given for the determination of hemoglobin and the oxygen capacity of blood.

The third part of the book contains a rather complete list of modern quantitative methods for the analysis of blood. Two methods which especially interested the reviewer were the determination of uric acid using uricase and the determination of creatinine using creatinine-destroying bacteria. The quantitative analysis of urine comes after methods for blood, followed by methods for the pathological constituents of the urine.

The first 13½ pages of the appendix contain, in addition to a table of atomic weights and a one-page table of logarithms, a very complete set of directions to the student regarding the organization and conductance of laboratory work. These directions are helpful and much to the point, as the reviewer can testify from his own experience. The latter part of the appendix contains full descriptions for the preparation of reagents used in the course.

The author has fulfilled his purpose admirably. The book will be valuable to the elementary student, as it doubtless has been in the past, on account of its straightforward and understandable explanations and descriptions of experiments as well as for the logical arrangement of laboratory work; it will be an aid to the research worker and to the teacher because of the well-chosen tests and quantitative methods. It has been easy for the reviewer to appreciate that this manual was not hurriedly thrown together, but is instead a carefully constructed piece of work achieved only as the outcome of many years of research, of experience in the laboratory, and of contact with students. Those who choose this book either for their classes or for their own use will have every reason to be satisfied.

JAMES B. SUMNER

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ITHACA, NEW YORK

HIGHER CHEMICAL CALCULATIONS. *A. J. Mee*, M.A., B.Sc., Head of the Science Department, Glasgow Academy. First American Edition. Chemical Publishing Co., Inc., Brooklyn, N. Y., 1941. viii + 184 pp. 4 figs. 12 × 18.5 cm. $2.00.

This book contains problems, with answers, within the following fields: gases, equivalents and atomic weights, stoichiometry, solutions, the properties of liquids, chemical kinetics and equilibria, electrolysis, equilibria in electrolytes, electrochemistry, and thermochemistry. Brief explanatory paragraphs and examples precede each section. A table of approximate atomic weights is limited to thirty-seven of the more familiar elements. Four-place logarithms and antilogarithms are included.

The problems seldom approach and never surpass in difficulty those commonly found in standard physical chemistry texts. In fact, many of the problems are of a type to be found in almost any general college chemistry text. The title of the book is therefore, by American standards, definitely misleading.

The book is well bound and printed, and seems to be comparatively free from errors. However, certain deviations from current practice in this country will probably make the book unacceptable except as a source of occasional miscellaneous problems for teachers. An example of such deviations is the use of molecular depression constants based on 100 g. rather than 1000 g. of solvent. "Vapor density" is defined on page 4 as half the molecular weight of the gas. There is also a fine disregard for significant figures in the table of answers.

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PERKIN AND KIPPING'S ORGANIC CHEMISTRY. *F. Stanley Kipping*, Professor Emeritus, University College, Nottingham, and *F. Barry Kipping*, University Lecturer, Cambridge. Third Edition. Thomas Y. Crowell Company, New York City, 1941. xxiii + xxvi + 1029 pp. 45 figs. 3 charts. 14 × 19.5 cm. $6.00.

In the third edition of PERKIN AND KIPPING'S ORGANIC CHEMISTRY the authors have made no radical changes from the previous edition either in method of approach or arrangement of material. They have, however, incorporated Part III with Parts I and II in a one-volume text, thereby giving to the student not only the fundamentals of organic chemistry but a source for more advanced material. The purpose of the revision is to include the recent developments in organic chemistry in theoretical interpretations, in new synthetic methods, and in commercial applications. This has been done quite successfully by modified statements and insertions without involving any great change in the greater part of the text.

In Part I the most significant change is the inclusion of the commercial preparations of various aliphatic compounds. These are indicated in the text and summarized at the end of Part I in two charts giving the products manufactured from "cracked" petroleum, from carbon monoxide, and from acetylene and ethyl alcohol. These charts show the interrelationships of the compounds and give the page references for the relevant reactions. In view of the importance of the direct nitration of the paraffins it is surprising that the authors make no mention of this, even in a footnote.

In Part II a number of preparative methods have been added; for example, the Clemmensen reduction of aldehyde and ketone for the preparation of the homologs of benzene, the preparation of phenol from chlorobenzene, and diazomethane from the nitroso derivative of methyl urea. The important synthesis of phenanthrene derivatives by the condensation of *o*-nitrobenzaldehyde (or derivatives) with phenylacetic acid is outlined. A number of important antiseptics such as "Chloramine T" and the acridine derivatives, acriflavine and proflavine, are included. A paragraph on sulfanilamide, its preparation and therapeutic importance, has been introduced. A general but somewhat limited review of the vitamins is given in Part II but no mention is made of vitamin $B_6$, of vitamin K, nor of the chemical nature of vitamin E either here or in Part III. The importance of nicotinic acid is not indicated. The discovery of the metallic phthalocyanines and their use as pigments is indicated but very little emphasis has been given to plastics and to polymerization processes, which are so significant today.

Throughout Part I and Part II there are suggestions of the interrelationship of bond "strength" and structure and the structural formulas of a number of compounds have been changed in terms of the electronic theory of valency. This is especially true in the case of a number of nitrogen compounds whose structures include semipolar bonds. The distribution of the fourth carbon valency in aromatic compounds is left for discussion in Part III.

It is in Part III that the most marked difference between this edition and the preceding one occurs. Two new chapters have been introduced as well as some significant changes in other material. In some cases the changes are in theoretical interpretations; in others they are the results of new experimental work. The discussion of the stereoisomerism of the allenes, oximes, and hydrazones has been modified considerably. The configurational formulas have been given in terms of the accepted convention. The section on fermentation has been rewritten from the point of view of recent investigation, and the more important fermentation processes are outlined in a chart giving the various stages occurring in each process.

One of the new chapters is devoted to the theory of resonance. A simple non-mathematical discussion of resonance is given and its difference from tautomerism is emphasized. In most compounds evidence of resonance is drawn from dipole moment and electron diffraction measurements. Chelation in a compound like *o*-nitrophenol is interpreted as resonance and the association of alcohols is similarly interpreted as intramolecular resonance. No mention is made of hydrogen bonding. The theory of resonance is also suggested as an interpretation of the intensity and stability of dyes.

The revised text will be welcomed by those organic chemists already familiar with the PERKIN AND KIPPING ORGANIC CHEMISTRY, who like it because of its completeness and arrangement. This arrangement whereby the material may be used for either the beginning or more advanced student is maintained. Those unfamiliar with the text will find it most comprehensive and up to date, a most valuable book to possess. It is an excellent reference text for any student of organic chemistry.

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LABORATORY MANUAL FOR GENERAL CHEMISTRY. *Albert L. Elder*, Professor of Chemistry, Syracuse University. Harpers and Brothers, New York City and London, 1941. xviii + 259 pp. 18 × 25.5 cm. $2.00.

The manual is bound with plastic to permit a flat opening and is covered with a flexible synthetic cover. The work is designed to keep a good student busy four hours per week for a school year. Topics are presented in the same order as they are in the text by the same author. The experiments are generally short and definite. Space for entering data and answering questions is provided. Blanks are provided for the student's name and the date at the beginning of each experiment and the paging permits each of the 78 experiments to be handed in separately. The data which appear at the back of the ordinary book are presented in the introductory pages of this manual. The directions are clear and definite and nearly all of the experiments are suitable for beginners. Teachers who feel that preparation of phosphine and arsine are too dangerous for large groups of freshmen can omit parts of experiments 50 and 51. The questions following each experiment require for their answers: close observation, recollection of other relevant information, and clear thinking. A very few statements might be misinterpreted. For instance, steel wool is wrapped around the end of a piece of picture wire, because "it is easier to ignite the steel wool first; this functions like a match head." This manual uses definite, prescribed experimentation, and encourages close observation and extensive interpretation of results, rather than semi-independent experimentation and undirected interpretation.

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DYES MADE IN AMERICA. *W. Haynes*, former publisher of *Chemical Industries*. Calco Chemical Division, American Cyanamid Co., Bound Brook, N. J., 1941. 61 pp. 27 figs. 22.9 × 30.5 cm.

In conjunction with the celebration of its twenty-fifth anniversary, Calco Chemical Division, American Cyanamid Company, has prepared this account of the development of the American dyestuff industry—from its beginning as a result of the shortage of coal-tar dyes, caused by the interruption of shipments from Germany during World War I, to its present established position. Learning organic chemical synthesis from the ground up, beginning with the scrupulous purification of raw materials to insure the occurrence of specific desired reactions, the research chemists of Calco proceeded from a small beginning to lay a foundation for the sound business the industry has now become. The struggle to get away from the stranglehold of the Dye Cartel, which had eliminated American competition quite effectively, resulted in the formation of the Chemical Foundation after the war, largely through the efforts of the late Francis P. Garvan. This quasi-public corporation was established to buy all available patents relative to chemicals and to license their use for a small, uniform fee to any *bona fide* American manufacturer.

The book is illustrated with line drawings and photographs of the various steps in the process of dye-making, and with full-color pictures of various fabrics, leather, paper, and plastics, representing the final result of all this research and industry. The monograph is both informative and interesting.

PROTECTIVE AND DECORATIVE COATINGS, PAINTS, VARNISHES LACQUERS, AND INKS. Volume I. Raw Materials for Varnishes and Vehicles. *Joseph J. Mattiello*, Ph.D., Technical Director, Hilo Varnish Corporation, Editor. John Wiley and Sons, Inc., New York City, 1941. xii + 819 pp. 78 figs. 15 × 23 cm. $6.00.

This is the first of a three-volume treatise on the subject. Volume II will be devoted to pigments, and Volume III to manufacturing and special studies. The editor states that the purpose of the book is to supply basic data and information pertaining to protective and decorative coatings, to serve the needs of technically trained graduates who enter the industry, and to aid more experienced technologists.

Forty-five specialists in various branches of the subject have contributed as authors to the introductory survey and to the twenty-nine chapters which comprise this volume. In addition, each chapter has been reviewed by at least four other competent technologists. This should assure the reader that the information provided is well chosen and authentic.

The introduction sketches the history, present development, and probable future of the paint and varnish industry. Drying oils are discussed in the first six chapters. Various natural and synthetic resins used in coatings are the subjects of sixteen chapters. A chapter on driers, five chapters on solvents and thinners, and a chapter on asphalt paints are provided. The final chapter deals with ethylcellulose in lacquer technology.

There are described in considerable detail the sources, methods of production and refining, properties, chemical reactions, and technical uses of various raw materials of the industry. Tables of useful data are presented throughout the book.

As stated in the preface, "The paint and varnish industry. . . has been a development of the arts, but now the industry is on the threshold of becoming a science." One of the authors mentions that a standard book of varnish formulas was reprinted fourteen times from 1736 to 1900 with only a few minor changes, and suggests that until fairly recently a chemist or engineer was a curiosity in the industry.

The book itself is convincing evidence of the change which has occurred. It exhibits a gratifying effort by the various authors to interpret the behavior of the materials under discussion in terms of physical and organic chemistry. It is apparent that the industry is no longer satisfied to accept its raw materials as provided by nature, but that it will more and more demand products modified or designed and synthesized to meet its particular requirements.

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EXPERIMENTAL PHYSICAL CHEMISTRY. *Farrington Daniels, J. Howard Mathews*, and *John Warren Williams*, Professors of Chemistry, University of Wisconsin. Third Edition. McGraw-Hill Book Company, Inc., New York City and London, 1941. xvii + 460 pp. 121 figs. 15 × 23 cm. $3.50.

This book has become so well known in its earlier editions that little description is required. The same subdivision of material is retained and discussion of each experiment follows the plan used previously. The framework and about two-thirds of the better experiments remain, yet the revision is thoroughgoing.

There are 72 experiments (one more than before), yet there are 39 less pages than in the second edition. Since the theoretical discussion or the description of the apparatus or procedure has, in many cases, been considerably expanded, it is evident that sections II and III on "Apparatus" and "Miscellaneous" have had to be extensively abbreviated. They are still very good, but one senses a losing struggle to serve two masters—to have a first-class laboratory manual which is also a fairly adequate reference book of physical chemical technics. In section II the authors have managed to add a bit on the electron microscope, the Tiselius cell, and isotopes. The discussions of capacity measurements and photochemical technics are very good. A chapter on the use of indicators has been added to section III.

A comparison with the second edition shows that 14 experiments have been abandoned, 11 extensively modified, and 15 have been added. Among the more notable of the latter group are photoelectric colorimeters and spectrophotometers, distilling columns, the hydrophil balance, moving boundary method for transference numbers, the polarograph, spectrography, and Raman spectra. It is regrettable that the old experiments on potentiometric titrations and indicators have been set aside, particularly to make place for "Exchange Reactions with Radioactive Bromine." Since the last requires either a fair amount of radium, or a cyclotron, or an electrostatic generator to produce neutrons, it is extremely unlikely to be used as a student experiment. Modernization of a laboratory manual may be overdone.

The references leave little to be desired. Typography, illustrations, and literary style are pleasing.

The reviewer considers this book one of the best of its kind. It is heartily recommended to all teachers and students. Even though another manual may be in actual use, this is a reference that should not be overlooked.

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TEST IT YOURSELF! CHEMISTRY EXPERIMENTS WITH CONSUMER APPLICATIONS. *Lawrence F. Tuleen, Willard L. Muehl*, and *George S. Porter*, Instructors of Chemistry, J. Sterling Morton High School and Junior College, Cicero, Illinois. Scott, Foresman and Company, Chicago, 1941. vi + 290 pp. 25 figs. 20 × 26.5 cm. $0.96. Teacher's Edition, $1.08.

If some morning you come staggering into your laboratory with a load of ice cream cones, ice cream, a few cases of soda water, coffee, headache remedies, alkalizers, and laxatives, your friends might infer that you were preparing for a large party with "hangovers." Another possibility is that your pupils are using these interesting items of common experience as the materials for their TEST IT YOURSELF! exercises. This laboratory manual deals entirely with substances used personally, in the home, or in the garage. The usual experiments on the preparation and properties of elements and compounds are entirely omitted.

The 14 units include 70 experiments grouped under the headings: Measuring; Household Chemicals; Cleansers and Softeners; Foods; Drinks; Health; Cosmetics; Textiles; Fuels; Lubricants; Anti-freezes; Protective Coatings; Inks, Dyes, and Stains; and Soils. A typical experiment consists of 4 parts: (1) preparation of the experimenter ("mind-set" is secured by (*a*) interesting discussion, (*b*) reference to 14 modern chemistry textbooks, (*c*) questions); (2) experimenting to find the facts, a process pointed toward amassing comparative data; (3) conclusions from the experiment in question form; (4) consumer applications in question form, frequently involving cost calculations.

This consumable manual is bound with rings which permit it to stay flat when folded to expose a *single* page. The user of the manual will need more items from the grocery and drug stores, but fewer of the staple chemicals. The directions call for the use of minimum amounts of materials, an economy of time, and reasoning from observations. They are expressed in clear, concise terms. No extensive extra equipment is needed.

The manual has a definite place in non-college-preparatory courses in secondary schools, for supplementary experiments in secondary schools, and for applied chemistry in junior colleges.

A teacher's edition of the manual contains a combination manual and answer-key. This is a somewhat unusual departure from present-day publishing practices.

Acids and bases are discussed using the theory of Arrhenius. Interpretation of the experimental findings will in some cases require assistance from a teacher, but, in general, care is taken to avoid having the pupil draw general conclusions from partial evidence. Careful reading bears out the first impression—very good!

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